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STATUS OF UGMS

AUGUST 14 & 18, 1988 EARTHQUAKE

UTAH GEOLOGICAL
AND MINERAL SURVEY

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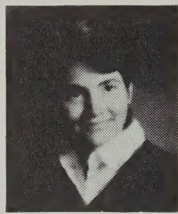

FROM THE DIRECTOR'S CORNER

Utah's "Sunset legislation" requires that state agencies periodically be reviewed and reauthorized. This year, UGMS is one of several agencies undergoing this review by the legislature. The procedure for reauthorization of UGMS and most other state agencies is for a committee of legislators to hold at least one hearing to review the activities of the agency and determine whether the agency is fulfilling the purpose for which it was established and if the need for the agency still exists. The committee reports to the next session of the legislature which then must either reauthorize the agency or terminate it.

Some agency heads approach these hearings with considerable trepidation but I was enthusiastic about the UGMS hearing. I am proud of the UGMS and its program and the hearing provided an opportunity to describe to a group of legislators what the UGMS does and why it is needed by the State. In addition, it provided an excellent opportunity for the UGMS management and staff to review the accomplishments of the organization and to reflect on how well we are meeting the needs of the state. Believing in this "sunset" concept, I voted for the legislation requiring these reviews. It is always interesting to experience the effects of legislation one has helped develop.

The committee addressed the following questions: 1) For what public purpose was the UGMS created? 2) Is the purpose still relevant? 3) To what extent has the UGMS operated in the public interest and accomplished its objectives? 4) Do budget, resource, or personnel constraints interfere with the legitimate functions of UGMS? If so, what are the implications of those constraints? 5) To what extent has the public been encouraged to participate in the adoption of rules by the division? 6) To what extent are the programs and services of the division duplicative of those offered by other state or federal agencies? 7) What would be the adverse effects on the public if the division were terminated? 8) If reauthorized, what changes in statute should be made to enable the division to better fulfill its public purpose? To answer these questions, the legislative staff and UGMS personnel compiled information for the committee; and the committee staff conducted extensive interviews with users of UGMS services and products and with organizations and individuals with direct knowledge of the UGMS.

The committee staff request included information on UGMS history, purpose, and programs. Several members of the UGMS staff were involved in compiling this material. The lead article in this issue is a summary of this information.

The findings of the committee were summarized as follows:

"Has UGMS operated in the public interest?"
- ☐ Services of the UGMS are vital to industry and government.
- ☐ Calibre of work is very good.
- ☐ Staff is accessible, cooperative, helpful.

"How would termination adversely affect the public?"
- ☐ Overall costs of information gathering would mushroom as industries and government agencies duplicate efforts.
- ☐ Lost mineral development opportunities.
- ☐ Individual state agencies would have to hire geologists.
- ☐ Public safety threatened due to lack of awareness of hazards.

"What constraints interfere with UGMS' mission?"
- ☐ Fluctuating level of mineral lease money.
- ☐ Isolated location at Research Park.

I was pleased with the committee's reaction to the review of UGMS. The committee feels, as I do, that the UGMS is staffed with dedicated employees who are efficiently performing a service that is essential to the state.

Status of the Utah Geological & Mineral Survey, 1988

by Genevieve Atwood

Virtually all states have recognized the need for geologic expertise in developing and managing natural resources and providing protection from geologic hazards and have established state geological surveys. Some state surveys are even older than the U.S. Geological Survey. State surveys vary considerably in size and mission depending on the perceived needs and resources of the state.

Geology had an important effect on the prehistoric residents of Utah and became increasingly important when permanent settlements were established in the 1840s. Those attempting to develop the mineral resources of Utah were well aware of the importance of geology to the success of their activities, but those engaged in other types of development were often not aware of the importance of geology until problems related to geologic hazards developed. We still have not experienced all of the geologic hazards that Utah has in store.

HISTORY OF UGMS

The major early geologic studies (1870-1910) in Utah were made by federal surveys, especially by the U.S. Geological Survey. These federal surveys were concerned with all aspects of the geology of Utah and some of the outstanding research of that era was done in Utah by such "giants" of geology as Gilbert (Lake Bonneville and the Henry Mountains), Powell (the Colorado River), Dutton (the Colorado Plateau), and Butler (ore deposits of Utah). With no state or local government expertise in geology, the responsibility for local leadership on geologic problems fell largely upon the University of Utah. James E. Talmage, professor of geology and president of the university, was an early leader in developing geological expertise at the University of Utah.

Utah's geological survey was authorized by the legislature in 1931 but had no funding or staff until 1941. Then it was incorporated into the Utah State Department of Publicity and Industrial Development as the Utah Geological and Mineralogical Survey with a small staff and budget and with the primary objective of stimulating the development of the state's mineral resources. In 1949, the UGMS was transferred to the School of Mines and Mineral Industries in the University of Utah but the staff and budget remained small until 1961. Much of the UGMS effort in these early years was in the publication of work by non-UGMS authors.

In 1961, the UGMS began a period of growth with an expanding staff and budget. More attention was focused on economic geology and geologic problems of direct and immediate interest to the state. The Utah Geological and Mineral Survey was made a part of the Department of Natural Resources in 1973. Major cooperative programs were developed with the Federal government, which became an important source of funding for UGMS programs. Economic geology has remained the largest activity in the UGMS but in recent years applied geology (investigations related to engineering geology and geologic hazards) and multipurpose geologic mapping have received more emphasis.

The mission and legislation authorizing the UGMS are stated in the Utah State code. In order to address the questions posed in the legislative review as to whether the missions of UGMS is still justified, and if the UGMS is functioning effectively in these areas, the missions were grouped into the following:

STATUTORY MISSION I — Provide accurate, reliable geologic information to the public, industry, universities, governmental agencies and others by preparing, publishing, distributing and selling maps and reports embodying the work accomplished by the UGMS and others.

STATUTORY MISSION II — Collect and preserve reports, data and samples related to exploration, development and construction activities in Utah, and to maintain certain types of confidential information.

STATUTORY MISSION III — Advise state and local agencies. Specifically, assist governmental agencies in their planning, zoning, and building regulations related to geologic hazards and resources. Investigate the mineral resources of state lands to contribute to the beneficial administration of these lands.

STATUTORY MISSION IV — Collect and distribute information on mineral, energy and water resources (including geothermal energy and mineral-bearing waters such as Great Salt Lake) with special reference to economic content and availability for utilization.

STATUTORY MISSION V — Identify and investigate topographic and geologic hazards (particularly earthquake hazards) and, at the request of state and local governments, review the siting of critical facilities.

STATUTORY MISSION I

Provide accurate, reliable geologic information to the public, industry, universities, governmental agencies and others by preparing, publishing, distributing, and selling maps and reports embodying the work accomplished by the UGMS and others.

Is this mission still justified? The need to make geologic information readily accessible increases continuously. As the exploration for and development of geologic resources becomes more sophisticated, the need for and ability to use a wide variety of geological information increases. Most land-use decisions require geologic information, as do the design and construction of many structures. Many resesarch projects build on a base of existing geologic information and the general public is becoming an increasingly important user of geologic information. To be effective in most uses, this information must be available upon demand and the maps, reports, data bases, and other sources must be available when the need develops. Thus, it is essential that the UGMS continue this mission of supplying this information.

Measurement of UGMS effectiveness. The primary measurement of UGMS effectiveness in performing this mission is the quality and number of publications produced. The list following this article gives an idea of the UGMS contribution to enhanced State revenues. The UGMS is continuously producing a wide variety of publications designed to meet the needs for geologic information in Utah. A glance through *Recent Publications* in each issue of *Survey Notes* should make this evident. In addition to the formal and informal publications, the UGMS has developed several data bases that can be accessed by the public. A special information group answers most public inquiries and the technical staff is available to respond to inquiries requiring special technical expertise. Special field reviews of major field projects are held and the potential users of the information that has been developed are invited to attend. Workshops are held to disseminate information and special instruction is provided to users of information.

Additional resources or legislation needed. The techniques for collecting, compiling, and disseminating geologic information are developing rapidly. Computers have become an essential part of the UGMS operation and this use is expanding rapidly. The UGMS has been able to keep abreast of these rapid changes with existing resources and no additional resources or legislation are required.

STATUTORY MISSION II

Collect and preserve reports, data and samples related to exploration, development and construction activities and maintain certain types of confidential information.

Is this mission still justified? This mission becomes increasingly important as the amount of geologic information increases. No other group has as a major mission the preservation of geologic information relating to Utah and if the UGMS does not perform this function, much valuable geologic information will be lost. It is important that the State of Utah have information available on the geology and resources of Utah to make decisions on State-Federal land exchanges and on land-use decisions such as wilderness designation. By having a central repository of geologic information, UGMS can encourage economic development of Utah's geologic resources and provide information about geologic hazards.

Measurement of UGMS effectiveness. The UGMS has the most up-to-date bibliography on Utah geology in existence. In addition to published reports, the bibliography contains references to many unpublished reports and maps. The UGMS maintains extensive collections of unpublished reports such as engineering geology studies, and maps such as old mine maps. Legislation approved in 1986 enables the UGMS to hold certain information confidential such as information donated by industry. The UGMS Sample Library contains cuttings and cores from many drill holes but until recently has not had the space or personnel to accept much of the material available. The sample library has recently moved into new space that is allowing for significant expansion.

New legislation or rules required. The UGMS does not have the funding or personnel resources to maintain a first-class sample library. UGMS Sample Library would be more beneficial to the state and to industry if companies were required to donate samples from significant wells. Likewise, industry should be encouraged to provide geologic information on state lands; companies doing exploration could improve the state's effectiveness to manage these state lands and resources. When UGMS moves, the new facility should be designed to make as much information easily available to the public as possible. Some state geological surveys have large reading rooms equipped with copying facilities as part of their library of maps, air photos, published and unpublished reports.

STATUTORY MISSION III

Advise state and local agencies. Specifically, assist governmental agencies in their planning, zoning, and building regulation related to geologic hazards and resources. Investigate the mineral resources of State Lands to contribute to the beneficial administration of these lands.

Is the mission still justified? As the need of state and local government agencies for geologic information has increased, so has the importance of this UGMS mission. Most agencies cannot justify adding a full-time geologist to their staff. Being able to call on the UGMS staff for support is a satisfactory way of meeting their need. Agencies that have geologists on their staff (such as the Department of Transportation) occasionally need the services of UGMS experts to supplement the expertise of the geologist on their staff and are major users of UGMS basic geological information. The Division of State Lands and Forestry uses information on the resources of the lands they administer in order to manage these lands.

Measurements of UGMS effectiveness. The best measurement of UGMS' effectiveness is the continuing number of requests received for assistance. In 1987, 16 state agencies, five county planning agencies, one county health department, three city planning/engineering agencies, one school district, and four state colleges and universities requested assistance from the UGMS. In addition, ten federal agencies requested UGMS assistance on problems relating to Utah and two adjacent state geological surveys requested assistance.

New legislation or rules required. None.

STATUTORY MISSION IV

Collect and distribute information on mineral, energy and water resources (including geothermal energy and mineral-bearing waters such as Great Salt Lake) with special reference to economic content and availability for utilization.

Is the mission still justified? Utah has a wide variety of mineral and energy resources and these resources have been very important in the economic development of the state. Water resources are also extremely important to the state. Wise management and development of state resources requires information on theses resources and the UGMS has the primary responsibility for assuring that this information is available when needed. The need for this information increases each year. The availability of information on resources has often been instrumental in attracting new industries to Utah and thus, the UGMS has an important role in encouraging economic development in Utah. Many land-use decisions that must be made by state, local and federal government agencies require information on the resources of the lands involved.

Measurements of UGMS effectiveness. The UGMS has obtained, through its own studies and through the work of others, much data on the resources of Utah. Much of this data has been included in reports published by the UGMS and is readily available. State-wide maps showing the location of known energy resources and major mineral deposits have been published by the UGMS. Several important developments of resources are a direct result of information in these UGMS reports. Much more information is in UGMS files and in the sample library. A primary objective of programs currently underway is to make this information easily accessible to the public.

New legislation or rules required. Geologic information acquired by private industry from exploration on state lands would be very useful to the state in the administration of these lands. We believe that the state should investigate ways to encourage industry to provide the information they collected on state lands to the state.

STATUTORY MISSION V

Identify and investigate topographic and geologic hazards (particularly earthquake hazards) and, at the request of state and local governments, review the siting of critical facilities.

Is this mission still justified? Utah is exposed to a wide variety of geologic hazards and actions. A knowledge of the hazards is required to minimize the risk from these hazards. As Utah becomes more developed, the importance of this information increases. An understanding by all decisionmakers, in government, private sector, and the public in general, is necessary to deal effectively with these hazards. Ordinances and codes relating to geologic hazards must be based on adequate geologic information.

Measurement of UGMS effectiveness. Through a cooperative program between the U.S. Geological Survey and the UGMS, topographic maps covering the entire state of Utah at a scale of 1:24,000 will be available at the end of 1989, and updating of these maps is a continuing part of the program. Topographic maps at this scale are essential to effectively work with geologic hazards. Also, by the end of 1989, the UGMS will have completed state-wide hazards maps showing the geographic distribution of major geologic hazards. Through efforts with the USGS, local universities, and numerous state and local agencies, the UGMS is working to make information on hazards available and to encourage the actions needed to reduce the risk from these hazards.

New legislation or rules required. The UGMS believes that legislation requiring the disclosure of information on geologic hazards when property is transferred would be a major advance in assisting companies and individuals in protecting themselves from geologic hazards. All critical facilities in the state should have a geotechnical site review, and the state should incorporate appropriate seismic standards into all public buildings built with state funds.

Coordination with other agencies

As part of the "Sunset" review, we examined the activities of the UGMS relative to other federal, state, and local government agencies and universities to determine if there was duplication or overlap and also to determine if there were areas where the need for geologic information was being neglected. We also attempted to determine how the activities of the UGMS impacted the private sector and served the needs of the individual residents of Utah.

The government agency that most nearly parallels the UGMS is the U.S. Geological Survey (USGS). The USGS spends several times as much money on projects in Utah as does the UGMS and much of the research done by the USGS outside of Utah has application to Utah's geology. It is important that the UGMS coordinate with the USGS to minimize duplication and to maximize the usefulness to Utah of work done by the UGSG. Twice a year, I meet for several days with the management of the USGS and other state geologists of the region to discuss the activities of the USGS and to describe the needs of Utah to the USGS. The UGMS and the USGS have an extensive cooperative program. It includes projects where scientists from both organizations work together toward common goals. An example of this kind of project is the mineral appraisal of the Delta 1x2 degree quadrangle. Other cooperatives involve joint funding support for work done by the UGMS (the Sevier Desert Quaternary geologic mapping project, for example, see *Survey Notes,* v. 21 no. 2-3) or joint funding for work done by the USGS (topographic and geologic quadrangle mapping). Some UGMS activities such as projects in the National Earthquake Hazards Reduction Program are supported entirely by the USGS. When responding to the floods and landslide events of 1983 threatened to overwhelm UGMS staff, we discovered another benefit of close cooperation with the USGS. They responded immediately to our request for assistance, sending experts to work directly with our staff to meet the emergency needs. The UGMS-USGS cooperation is an outstanding example of how two government agencies can work together to effectively accomplish the objectives of both state and federal programs.

The UGMS also has cooperative programs with the Bureau of Land Management and the Department of Energy involving work done by the UGMS on resource problems, and maintains contacts with the Bureau of Mines on resource issues and with the Forest Service and the Federal Emergency Management Agency (through the Utah Division of Comprehensive Emergency Management) on geologic hazards. Once each month, along with the directors of other Department of Natural Resources divisions, I meet with the heads of federal resource operations headquartered in Salt Lake City to discuss mutual concerns. The relations with federal agencies other than the USGS are not as effective as those with the USGS, but we do avoid major duplication and share information.

The UGMS has generally good working relations with individuals and departments in Utah State, Utah, and Brigham Young Universities concerned with earth science problems. Through our contract and grant programs, we furnish some support for research on geologic problems identified by the UGMS. The talent thus made available in these universities is an important supplement fo the UGMS staff.

As the state's lead geologic organization, the UGMS provides advice and assistance to all state agencies requesting it and attempts to provide geologic input to all state policy decisions where geologic considerations are important. The Division of State Lands and Forestry and the Division of Oil Gas and Mining provide funding support to the UGMS for resource work related directly to their programs and the Division of Community and Economic Development supports several UGMS projects designed to assist local communities and encourage economic development. When state agencies require continual participation of geologists in their programs, the UGMS encourages them to consider adding geologists to their staff with the specialties they require. UGMS continues to be available to assist these agencies with special problems and to assist the managers of these agencies in developing and administering these programs. Several state agencies now employ geologists. Some problems of duplication arise when the Utah State Code has assigned two or more state agencies overlapping functions. For example, the UGMS and CEM both have responsibilities relating to earthquake hazards. I meet periodically with the Director of CEM to discuss the activities of our two divisions to minimize the duplication and confusion. In some instances, the state's procedures and policies conflict with UGMS objectives. For example, the procedures for authorizing and funding state construction projects do not encourage adequate consideration of geologic hazards. In general, the UGMS is providing good geologic support to state agencies, but the information and talent available at UGMS is not always utilized by them.

The UGMS works well with most local government agencies. Because there is little geologic expertise within these organizations, there is little chance for duplication. Notable exceptions are Davis, Salt Lake, and Utah Counties. With funding and support from the USGS, the UGMS has assisted these counties in employing full-time geologists in their planning departments. The activities of these geologists are closely coordinated with related activities at the UGMS.

The UGMS avoids competition with the private sector. Our work clearly generates more work for private industry than we take away and our review activities are structured to improve the quality of some of this work. We are now involved on a project to determine what kinds of UGMS information and activities are most effective in stimulating the development of Utah's geologic resources.

Funding needs

If the funding and personnel resources were available to the UGMS, there are many things that could be done that would benefit the state. But considering the funding available to state government and the numerous demands on these funds, I conclude that the state's level of support to the UGMS is appropriate. As Director of UGMS, I am very concerned that we are not providing adequate salaries for some staff. The salary scale for state employees makes this impossible but as a result the UGMS attracts geologists who are not "money drivers." Some have a hyperactive social conscience and receive compensation by seeing the geology they do make a difference to society. Others are risk adverse and trade off the lower salary for the greater security of state employment. Others have additional outside income. The net result is that many highly qualified individuals turn down service to the state on purely economic grounds.

Conclusion

I think the "Sunset" review of the UGMS has been very effective. It has accomplished exactly what it was intended to do —assure the legislature that the organization is needed and functioning well. It has also provided an opportunity for the UGMS to assess our activities and identify activities needing more emphasis and areas where our operation can be improved.

Specific Examples Where UGMS Publications
Have Contributed to Economic Development
Which Enhanced Revenues to the Division of State Lands.

BULLETINS

UGMS PUBLICATION	COMMODITY	LOCATION	COMPANY	NOTES
Bull. 38, 39, 43, 45, 53, 57	Petroleum	Central Utah	Placid Oil	Invested over $100 million, specifically chose State sections as drilling locations
Bull. 41	Clay	Pelican Point	Interpace	
	Clay	Pelican Point	Interstate Brick	
Bull. 44	Silver	Silver Reef District	5M Mining Company	Leaching material from several mines (mining claims?)
Bull. 46	Vanadium, uranium	Thompson District	Cordero Mining, Co., etc.	Pittsburg Mine expanded
Bull. 54	Petroleum	Upper Valley Field	Tenneco	10-15 holes on State leases
Bull. 56	Dolomite	Delle	Utah Marblehead Lime	
Bull. 62	Gold, tungsten	New Klondike Property	New Klondike Mining Co.	Mining claims
Bull. 63	Gold	Lookout Pass	Freeport McMoRan	Mining claims
Bull. 64	Petroleum	Cache County	Mountain Fuel/Placid Oil	Spent more than $4 million on seismic exploration
Bull. 68	Copper, tungsten	Bwana, Maria, etc., Mines	West Toledo Mining Co.	Mining claims
Bull. 71	Oil shale	Kamp Kerogen	Geokinetics	State leases
	Oil shale	Sand Wash	Tosco	State leases
	Phosphate	Brush Creek	U.S. Steel	
	Tar sand	Raven Ridge	Western Tar Sands Inc.	
	Tar sand	Asphalt Ridge	Enercor	
	Tar sand	Asphalt Ridge	Sohio	
	Tar sand	Asphalt Ridge	Asphalt Ridge Energy	
Bull. 75	Clays, uranium	West Desert	Interstate Brick	
Bull. 78	Petroleum	Western Utah	Placid Oil	Exploration on state sections
Bull. 83	Gold	Yellow Hammer Mine	American Consolidated	Mining claims
Bull. 112	Coal	Trail and North Horn Mtn.	UP&L, Natomas	Increased reserves and value of all State sections
Bull. 116	Salts, brines	Great Salt Lake	Mineral companies, Public	Reference book
Bull. 115	Tungsten	Box Elder County	small companies	
Bull. 119	Petroleum	Kachina Field	Meridian	.5 million bbl production
	Petroleum	Kiva Field	Yates	

SPECIAL STUDIES

Spec. Studies 3	Coal	Escalante Area	UP&L	State lease
Spec. Studies 5	Petroleum	Rozel Point	All Minerals	
	Petroleum	Great Salt Lake	Amoco	
Spec. Studies 12	Alunite	Blawn Mountain	Alumet Inc.	
Spec. Studies 15	Coal	SUFCO Mine	Coastal States	
Spec. Studies 19	Tar sand	Asphalt Ridge	Enercor	
	Tar sand	Asphalt Ridge	Sohio	
	Tar sand	Asphalt Ridge	Asphalt Ridge Energy	
Spec. Studies 20	Coal	UP&L drilling project	UP&L	
Spec. Studies 22	Uranium	Woodruff Springs	Exxon	9 million ton ore body
	Uranium	Ticaboo	Plateau	9 million ton ore body
Spec. Studies 23	Clay	Pelican Point	Interstate Brick	
	Clay	Pelican Point	Interpace	
Spec. Studies 37	Tar sand	Tar Sand Triangle	Gulf Mineral Resources	
	Tar sand	Asphalt Ridge	Enercor, Sohio, Asphalt Ridge Energy Corp.	
	Tar sand	Raven Ridge	Western Tar Sands	
	Tar sand	Sunnyside	Standard Oil (Indiana), Great National, Mono Power, Amoco, Enercor	
Spec. Studies 49	Methane	Price River Mine	Occidental Petroleum	
	Methane	Soldier Canyon Mine	REI/Soldier Creek Coal	
	Methane	SUFCO Mine	Coastal States	
Spec. Studies 54-55	Coal	North Horn Mountain, East Mountain, Muddy Creek	Exxon, Arco	Leasing
Spec. Studies 63	Geothermal	Escalante Valley	Utah Municipal Power	
Spec. Studies 67	Geothermal	Washington County	Dixie Power & Light	Exploration

MONOGRAPHS

Monograph 1-3	Coal	Central Utah, So. Wasatch Plateau	IPP	Originally intended to go to New Mexico

MISCELLANEOUS

RI 199	Land development	Washington County	Div. State Lands	Need to develop general management plan
RI 200	Minerals	West Desert	Div. State Lands, BLM	Information for land evaluations
RI 212	Land development	Washington County	Div. State Lands	Resort development
WRB 25	Brines	Great Salt Lake	AMAX, Great Salt Lake Minerals, Morton	Alternative sources of brine
File Data	Brines, salts	Sevier Lake	W.D. Haden	Resource, processing data
Memo	Salts, brines	Sevier Lake	Mineral Leasing Task Force	Potassium lease holding increase analysis
Tech. Memo	Land development	Iron County	Div. State Lands	Ski resort
Tech. Memo	Land development	Garfield County, Bullfrog	Div. State Lands	Boat storage and restaurant
Tech. Memo	Land development	Iron County	Div. State Lands	Land exchange
Data Base	Oil well brines	Utah	Petroleum and mineral companies, Div. of Oil, Gas and Mining	Baseline data, reinjection programs, resource

MAPS

Map 24	Coal	Kaiparowits	Peabody Coal Co.	
Map 47	Tar sand	Tar Sand Triangle	Gulf Mineral Resources	
	Tar sand	Asphalt Ridge	Enercor, Sohio, Asphalt Ridge Energy Corporation	
	Tar sand	Raven Ridge	Western Tar Sands	
	Tar sand	Sunnyside	Standard Oil (Indiana), Great National, Mono Power, Amoco, Enercor	
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Map 58	Petroleum	Laketown area	American Quasar	Test well
Map 63	Coal	Book Cliffs	Pinnacle	Land acquisition
Map 72	Coal	Soldier Canyon	Sunedco	
Map 76	Coal	Pinnacle Mine	Tower Resources	Also used by BLM for leases
Map 77 and Bull. 115	Gold	Tecoma Deposit	Noranda/Western States	Mining claims
Map 90	Petroleum	T. 31 S., R. 9 E., sec. 24	Exxon	Exploration well

CIRCULARS

Circular 38	Diatomaceous earth	Bryce Canyon	Johns-Manville	Drilled deposit

OPEN-FILE REPORTS

OFR 87	Brines	Great Salt Lake	All mineral companies	Great Salt Lake baseline data
OFR 114	Gold	Keg Mountain Prospect	Freeport McMoRan	Mining claims
Sample Library	Petroleum	Statewide	Virtually all exploration companies	
	Gold	Mercur	Getty Minerals	
	Coal	Wasatch Plateau	numerous	Federal leases

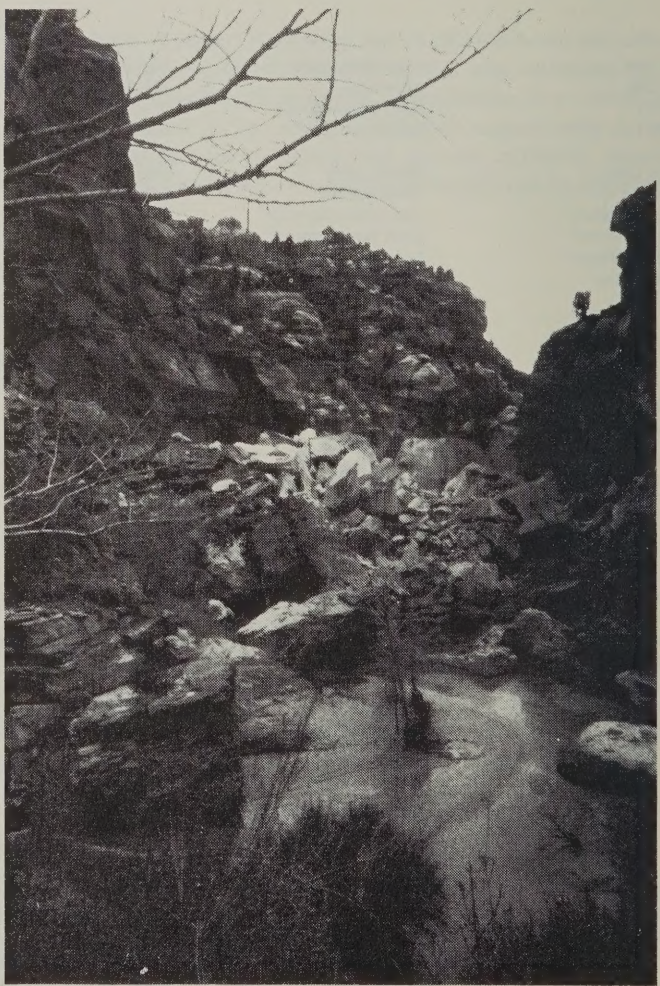
Rockfall in Hackberry Canyon, April, 1988

by Hellmut H. Doelling

A very large rockfall blocked off the trail in upper Hackberry Canyon, in SESWSW Sec. 21, T 40 S, R 1 W, in central Kane County. In mid-April, about 4½ miles from the mouth of the canyon, a section of cliff peeled off the west wall, and the debris knocked over and uprooted shrubs and brush on the far wall. The creek was dammed or restricted in its flow enough to create a small lake extending 100 yards upstream. At the time of my visit on April 28, the creek had worked through the debris and appeared unhindered in its flow, with the most extensive hole of the remaining lake about four feet deep.

The width of the canyon at this point is nearly ninety feet, with the height of the broken material some 35 to 40 feet above the creek level. Originating in the Kayenta Formation, probably as the creek undermined the west side of the canyon, the rockfall fell away as a large slab and broke into fragments, the largest of which are 35 x 35 x 20 feet.

The canyon, part of the Hackberry Canyon Wilderness area, is in the Calico Peak 7½-minute quadrangle, currently being geologically mapped at a scale of 1:24,000 by the UGMS. The map area is one of great scenic beauty with many interesting geologic features including the East Kaibab monocline, great toreva block slides, large areas of mass-wasting deposits, petrified wood, strata attenuation, and, as it now appears, large rockfalls.



On Sunday afternoon at 2:03 PM, the 14th of August, the San Rafael Swell earthquake (magnitude 5.3) struck Castle Valley, east of Castle Dale, in central Utah on the west flank of the San Rafael Swell. Many governmental and academic agencies responded to the earthquake because: 1) the geologic effects and damage from magnitude 5 earthquakes represent a significant earthquake hazard since they are more frequent than larger earthquakes, 2) earthquakes of this size are uncommon in the area and the event afforded a unique opportunity for scientific research, and 3) the earthquake occurred in an area of transitional seismic character between the Basin and Range and the Colorado Plateau.

The three following papers discuss various aspects of the earthquake and its foreshocks and aftershocks. The Utah Geological and Mineral Survey (UGMS) presents a compilation of geologic effects of ground shaking during the earthquakes including preliminary modified Mercalli Intensity data provided by the USGS National Earthquake Information Center. The University of Utah Seismograph Stations (UUSS) recorded the earthquakes with their established seismograph network, and the aftershocks with a portable network; the second paper is a seismological summary. The last paper is a report of damage and emergency response written by the Utah Divison of Comprehensive Emergency Management. Other agencies conducted post-earthquake studies which are also summarized briefly in these three papers. Water impoundment safety was evaluated by the Utah Division of Water Rights, Dam Safety group; the Bureau of Reclamation Dam Safety group; the U.S. Department of Agriculture, Soil Conservation Service, and Ferron Canal and Reservoir Company. The Castle Valley Special Service District checked pipes and springs. The National Earthquake Information Center sent questionnaires to post offices within 200 miles (300 km) of the epicenter to determine intensity distributions.

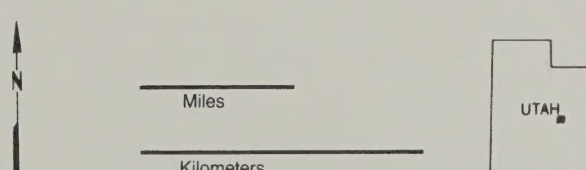
Geologic effects of the 14 and 18 August, 1988 earthquakes in Emery County, Utah

by
William F. Case
Utah Geological and Mineral Survey

Quaternary: Qa1 alluvium
Jurassic: Jms Morrison Formation, Salt Wash Sandstone Member
Jurassic: Js Summerville Formation
Jurassic: Jcu Curtis Formation
Jurassic: Je Entrada Sandstone
Jurassic: Jc Carmel Formation
Jurassic/Triassic JTRgc Glen Canyon Group: Navajo Sandstone, Kayenta Formation, Wingate Sandstone (Hintze, 1980)

contact:
fault (U = up, D = down)
photo lineament:
epicenter:

Figure 1. *Geology and aerial photograph of the epicentral area (from Kent, 1956a, b).*



Introduction

The Utah Geological and Mineral Survey (UGMS) investigated the epicentral region of the 14 and 18 August earthquakes in Emery County to document associated geologic phenomena, particularly rock falls and liquefaction features identified by T. L. Youd (Brigham Young University Civil Engineering Department, oral commun., 17 August, 1988). The local magnitudes (M_L) of the main shock (M_L 5.3) on 14 August and the largest aftershock (M_L 4.4) on 18 August are near the rock fall and liquefaction activation thresholds of M_L 4 and 5, respectively (Youd, 1985; Keefer, 1984).

The scope of work included literature research, personal interviews, telephone interviews, distribution of questionnaires, aerial photo interpretation, and a reconnaissance of the area within 30 miles (50 km) of the epicenter on 22-24 August, 1988. The reconnaissance included a search for rock falls and landslides in Buckhorn Draw and Wasatch Plateau canyons between Huntington and Emery, and liquefaction effects near the epicenter in Fuller Bottom on the San Rafael River, and at Huntington and Mill Site reservoirs. Because of the low magnitude of the earthquakes, there was no concentrated attempt to locate surface faulting in the epicentral region.

The most reliable proof of seismically triggered rock falls was eyewitness accounts of rocks falling or dust clouds. The accumulation of evidence from questionnaires and interviews indicates that perhaps hundreds of rock falls producing dust clouds, some enshrouding the eastern edge of the Wasatch Plateau, occurred within 25 miles (40 km) of the epicenter during the main shock. Isolated rock falls up to 70 miles (113 km) from the epicenter were sighted on 14 August. Circumstantial, post-event evidence of rock falls, such as rocks on roads or fresh cliff scars, were reported up to 80 miles (129 km) from the epicenter. The magnitude threshold of abundant, seismically induced rock falls appears to be between M_L 4.4 and 5.3; evidently no rock falls were noticed during the 14 August M_L 2.9 amd 3.8 foreshocks, even as close as 11 miles (18 km); one rock fall was triggered by the M_L 4.4 aftershock on 18 August.

Cracks due to liquefaction of saturated San Rafael River alluvium, 2.5 miles (4 km) from the epicenter, were discovered by Youd on 15 August, (oral commun., 17 August, 1988). A field inspection on 23 August noted similar cracks and a sand boil in saturated alluvium at Fuller Bottom on the San Rafael River, 1.2 miles (1.9 km) from the epicenter.

Geology

The epicentral region is at the western edge of the Colorado Plateau in the San Rafael Swell (Stokes, 1977). Cliffs of the Wasatch Plateau are west and the Book Cliffs are north of the epicenter. Bedrock exposed within 10 miles (6 km) of the epicenter, from west to east, consists of the Jurassic Entrada Sandstone; shale members of the Jurassic Carmel Formation at the epicenter; and, exposed in incised valleys, the Jurassic/Triassic upper Glen Canyon Group which includes the Navajo Sandstone and Kayenta and Wingate Formations (figure 1) (Hintze, 1980; Kent, 1956a). Bedding is nearly horizontal, dipping gently to the west. North-trending faults displace the Mesozoic bedrock but there is no evidence of displaced Quaternary units (Kent, 1956a; Roger Fry, Utah Power and Light, oral commun., 1 September, 1988).

Preliminary Modified Mercalli Intensities

The United States Geological Survey National Earthquake Information Center (NEIC) sent questionnaires to 273 post offices within 200 miles (300 km) of the epicenter to determine the damage and estimate the intensity of ground shaking experienced by each community during the major shock on 14 August and the 18 August aftershock. Carl Stover (NEIC, written commun., 21 September, 1988) provided preliminary data for the main shock to UGMS for informational purposes. The distribution of intensities and questionnaire destinations are shown on figure 2. Although the data are too preliminary for scientific conclusions, they do indicate the general pattern of ground shaking effects.

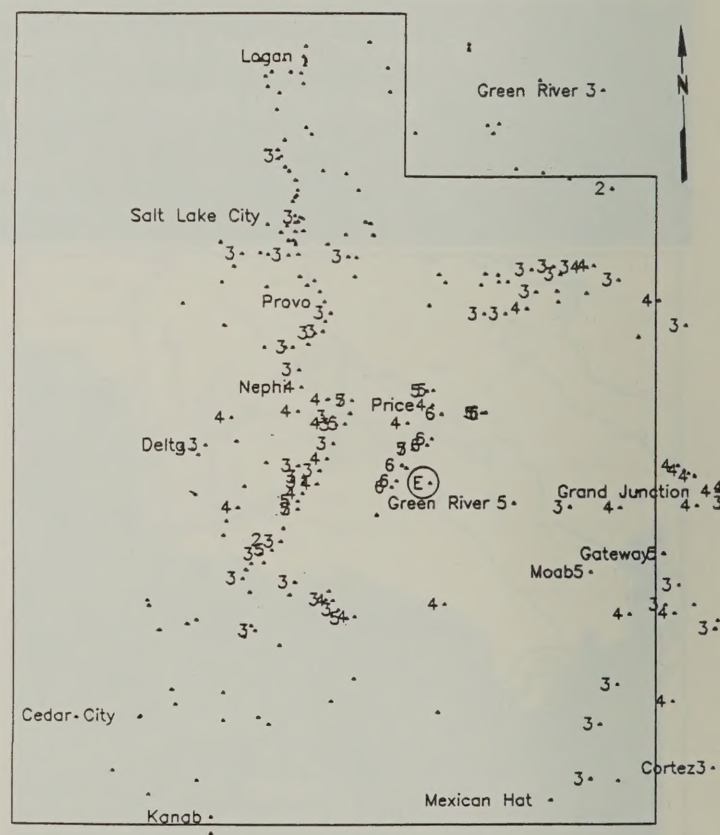


Figure 2. Preliminary Modified Mercalli Intensity Map of 14 August, 1988, 1403 hrs MDT (NEIC).

Ⓔ EPICENTER Scale 1:3,000,000

▲ Post Office to which questionnaire was sent.

5 Preliminary Modified Mercalli Intensity
(note: Locations without designated intensity did not feel the shock or did not return the questionnaire)

The highest preliminary Modified Mercalli Intensity, VI, was assigned to the Emery County communities of Clawson, Cleveland, Elmo, Ferron, Orangeville, and Carbon County towns of Sunnyside and Wellington, all within 38 miles (61 km) of the epicenter. Shaking at intensity VI will crack low quality or aged masonry, and cause loose bricks, stones, or pieces of plaster to fall (table 1). Almost everybody in the area, indoors or outdoors, feels the shaking and has difficulty walking or standing. Intensity V effects were reported in 13 communities within 105 miles (170 km) of the epicenter including the Utah towns of Teasdale, Annabella, Fairview, and Moab; and Gateway, Colorado. The total felt area of the main shock ranged from Brigham City, 174 miles (280 km) northwest of the epicenter; Delta, 97 miles (156 km) to the west; Albuquerque, New Mexico, 353 miles (567 km) to the south; Bluff, 145 miles (233 km) to the southeast; and Golden, Colorado, 295 miles (475 km) to the east (Carl Stover,NEIC, written commun., 1988; Salt Lake Tribune, 15 August, 1988; Nava and others, this issue). The distribution of reported effects shows higher intensities to the east through the Colorado Plateau than west into the Basin and Range. The lack of reporting stations to the west accentuates this effect, but it does indicate a difference in attenuation of ground shaking in different directions. The eastern extension of low attenuation through the Colorado Plateau may be due to the relatively continuous and unfaulted bedrock of the plateau. Gateway, Colorado, 106 miles (170 km) from the epicenter, showed effects of intensity V, whereas to the west into the Basin and Range which is characterized by intensely folded and faulted bedrock, the most distant intensity V was at Salina only 58 miles (93 km) from the epicenter. There were few reports from communities southwest of the epicenter, and either the earthquake was not felt or the questionnaires were not returned.

Geologic Effects

Rock Falls

Dust clouds produced by rock falls were the most visible effect of ground shaking. Falls and dust continued for almost an hour after the shocks, giving residents the time to take pictures and video tape the dust clouds (figures 3, 4).

Figure 3. *Dust on Wasatch Plateau cliffs resulting from rock falls triggered by main shock on 14 August, 1988. The cliffs are west of Huntington, approximately 20 miles (30 km) northwest of the epicenter. Photograph by Darrel V. Leamaster, Castle Valley Special Service District, Huntington, Utah.*

Figure 4. *Dust from rock falls triggered by main shock, approximately 2 pm, 14 August, 1988. View looking toward epicenter, 11 miles (18 km) south of BLM Cedar Mountain picnic area. Photograph by Terry A. Humphrey, Bureau of Land Management, Price, Utah.*

A tabulation of UGMS questionnaires revealed that rock falls were triggered by the main shock and the 18 August aftershock. Figure 5 shows the distribution of rock falls caused by ground shaking based on eyewitness accounts of rocks falling and the associated extent of dust clouds. The earthquakes occurred in an area where many sandstone cliffs provide source material, that is, the Wasatch Plateau, the Book Cliffs, and the Canyonlands area. It is fortuitous that the main shock occurred on Sunday afternoon; sightings of rock falls from isolated population centers were supplemented by reports from people on Sunday afternoon outings.

Figure 5. Extent of witnessed rock falls and dust clouds triggered by 14-18 August, 1988, Emery County earthquakes.

EXPLANATION
Individual rock fall [locations]: ● (14 August event); (18 August event)
Generalized area of dust clouds produced by rock falls on 14 August:
Epicenter: O
Approximate scale 1:1,100,000
Relief map from Ridd (1963)

The majority of rock falls and/or associated dust were reported along the eastern cliffs of the Wasatch Plateau from Huntington Canyon south to the Emery area, about 24 miles (40 km) from the epicenter, and in Buckhorn Draw, a tributary of the San Rafael River, within 12 miles (19 km) of the epicenter. Most of the questionnaires reported dust which obscured the cliffs of the Wasatch Plateau (figure 3). Individual rock falls were seen in Huntington Canyon and east of Ferron. The rock falls were so numerous in Buckhorn Draw that a "curtain of dust" was produced which was visible from the Cedar Mountain picnic site on Red Plateau (figure 4), and the community of Huntington. Rock falls were also witnessed in Buckhorn Draw. Isolated rock falls were seen in the Book Cliffs at Columbia and Balanced Rock near Helper, and near Dead Horse Point State Park 70 miles (115 km) from the epicenter. Evidence of rock falls such as a boulder in the road, an unusual accumulation of clasts below a road cut, or a fresh scar on a cliff with rock fall clasts at its base were noted in Spanish Fork Canyon, Soldiers Summit, and Price Canyon (U.S. Highway 50); Salina Canyon (Interstate 70); and on the La Sal Mountain loop road near Moab. These reports are considered less reliable because the rock falls were not witnessed and were not necessarily attributable to ground shaking. Evidence indicates that, based on the dust cloud extent, possibly hundreds of rock falls occured within 25 miles (40 km) of the epicenter; isolated rock falls were intiated up to 70 miles (113 km) from the epicenter; and there is a possibility that some rock falls, as much as 80 miles (129 km) from the epicenter, were triggered by ground shaking.

Geologic units involved in the rock falls included the: 1) Cretaceous Mesa Verde Group sandstone (Hintze, 1980) along the eastern face of the Wasatch Plateau and at isolated spots in the Book Cliffs, particularly cliffs of red "clinker" beds consisting of sandstones that were melted and hardened by prehistoric underground coal fires (Sam C. Quigley, oral commun., 23 August, 1988); 2) Jurassic Entrada Sandstone (Kent, 1956a) within 3 miles (5 km) of the epicenter; 3) Jurassic/Triassic Glen Canyon Group (Hintze, 1980) sandstone in Buckhorn Draw and near Dead Horse Point; 4) Jurassic/Triassic Glen Canyon Group and/or Permian Cedar Mesa sandstone (Helmut Doelling, Utah Geological & Mineral Survey, oral commun., 18 October, 1988) in Lockhart Basin near Canyonlands National Park (Salt Lake Tribune, 15 August, 1988); and 5) Tertiary intrusive (Hintze, 1980) rocks which rolled down scree slopes onto the La Sal loop road southeast of Moab.

The magnitude threshold of abundant rock falls triggered by ground shaking appears to be between M_L 4.4 and 5.3. No rock falls were noticed during the 14 August M_L 2.9 and 3.8 foreshocks, even as close as 11 miles (18 km) at Cedar Mountain picnic area (Terry A. Humphrey, BLM, written commun., 6 September, 1988). Guy Seely (written commun., 12 September, 1988) saw a single rock fall east of Ferron triggered by the M_L 4.4 aftershock on 18 August.

Liquefaction

Cracks caused by liquefaction of saturated alluvium were noted by T. Leslie Youd (oral commun., 17 August, 1988) on 15 August. Youd found small cracks parallel to the San Rafael River approximately 2.5 miles (4 km) from the epicenter. Possible liquefaction cracks were noted in recent alluvium at Fuller Bottom on the San Rafael River, 1.1 miles (1.8 km) from the epicenter on 23 August, 1988 (figure 6). The cracks were parallel to the river, and ranged from 3-5 feet (1-1.5 m) long and as much as 1 inch (2.5 cm) wide and deep near the stream bank, and less pronounced approximately 10 feet (3 m) from the river's edge. A 5-inch (13 cm) diameter sand boil was ejected from a crack in the alluvium. Tingey and May (this issue) report no conclusive evidence of liquefaction in Cottonwood and Huntington Creeks.

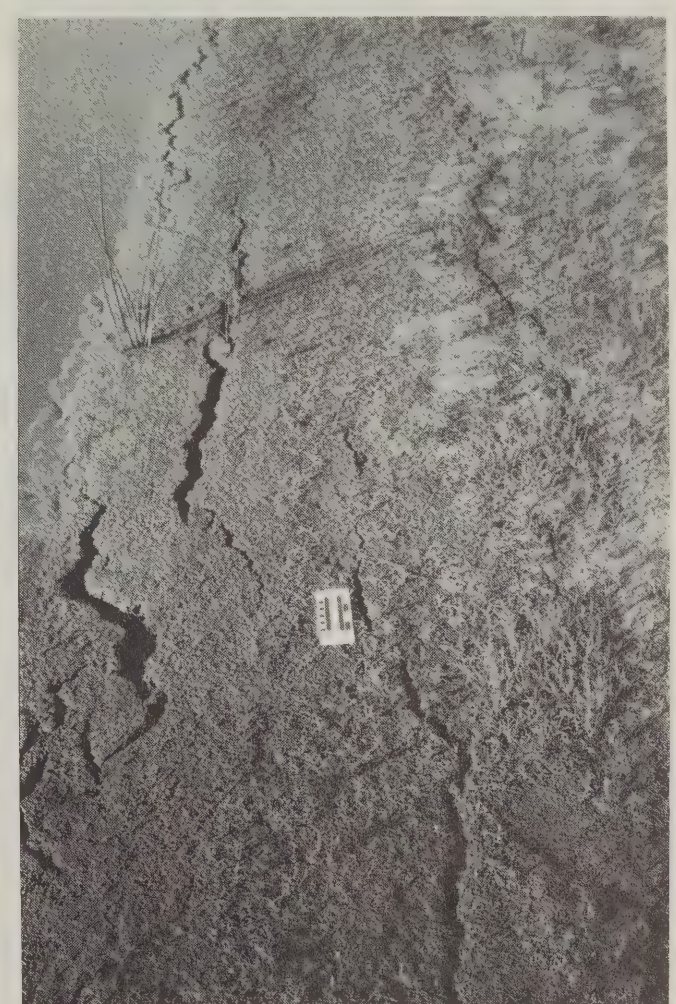


Figure 6. *Ground cracks in wet alluvium, Fuller Bottom, San Rafael River, approximately 1.5 miles (2.25 km) southwest of epicenter. Black bars on scale are centimeters on left and inches on right side. San Rafael River is evident in upper left-hand corner. Photograph taken 23 August, 1988 by William F. Case, Utah Geological and Mineral Survey.*

Miscellaneous Observations and Recordings

Darrel V. Leamaster, district manager, Castle Valley Special Service District, reported increased spring flow following the 14 August earthquakes. Flow increased from a four-year maximum of 85 gallons per minute (0.00 5m^3/s) before the earthquakes to 133 gallons per minute (0.008m^3/s) after the shocks. The spring is located in Tie Fork Canyon, a tributary of Huntington Canyon drainage, 30 miles (48 km) from the epicenter. Two other nearby springs in Big Bear Canyon and Little Bear Canyon did not experience any change in flow.

Paul Crawford (Ferron Canal and Reservoir Company) reported seeing water that had been wave-splashed on the upstream face of Mill Site Dam, approximately 3 feet (1 m) above static water level. The surge may have been caused by ground shaking; no landsliding into the reservoir was noticed. Standing waves on the water surface were not evident. Crawford noted that the lake water was slightly turbid. Mill Site Dam is located about 20 miles (32 km) from the epicenter. Surges or standing waves were not noticed on Huntington Lake, 17 miles (27 km) from the epicenter, according to Kean Luke, Huntington Lake State Park superintendent (oral commun., 23 August, 1988). Luke noted that since the lake was covered with Sunday afternoon boaters, standing waves or surges were probably obscurred.

The strong-motion seismograph database of Utah earthquakes more than doubled in size with the addition of recordings of ground acclerations during the main shock and the 18 August aftershock at Joes Valley Dam, 26 miles (42 km) from the epicenter. Accelerometers recorded peak accelerations of 0.11 g on the crest of the dam and 0.06 g midslope during the largest shock, with 0.05 g at the crest while the midslope instrument was untriggered during the aftershock (Dan Grundvig, Bureau of Reclamation Dam Safety, oral commun., 11 October, 1988).

Acknowledgements

Carl Stover and Lindie Brewer (NEIC) freely provided their questionnaire data and offered valuable assistance. The following geologists and scientists who experienced the shaking provided essential data for the investigation: Sam C. Quigley (Andalex Resources), Roger Fry (Utah Power & Light), Darrell Leamaster (Castle Valley Special Service District), and Paul Crawford (Ferron Canal and Reservoir Company). Dan Grundvig (Bureau of Reclamation), Robert C. Rasely (U.S. Soil Conservation Service), and T. Leslie Youd (Brigham Young University Civil Engineering Department) freely provided much data. Dottie D. Brockbank (Public Information Officer, Department of Natural Resources) called for rock fall data in local newspapers and Chris Wilkerson (UGMS) forwarded questionnaires and background materials to respondents and collected replies. The response to the newspaper request was heartening. Much important rock fall information, such as distribution and timing of rock falls, was reported. Many had very scientific and useful commentary. Photographs were included with the completed questionnaires and there were several offers to copy video tape scenes. Questionnaires were returned by: Terry A. Humphrey, Price; Allan Sorensen, Clawson; Sharon A Emery; Lillian L. Cassano, East Carbon; Elisa Pehler, Price; Arvetta Satterfield, East Carbon City; Leslie Roye, Price; Guy Clawson; Susie Baca, Sunnyside; Lee Sjoblom, Dead Horse Point Park; J. Rulon Nelson, Ferron; Renee Callor, Helper; and Darrell Leamaster, Castle Dale.

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Table 1: MODIFIED MERCALLI INTENSITY: *Description and effects*[1]

Intensity (Magnitude[2])	*Personal Reactions*	*Vehicle Response*	*Structural Response of Buildings*	*Miscellaneous Effects*	*Geologic Effects*
I (1-2) Microearthquake	Barely felt by sensitive few, some dizziness, nausea.			Animals restless. Trees, structures, liquids, bodies of water may sway. Doors may swing very slowly.	Small fractures near epicenter of small earthquakes or far from large quake epicenter[3].
II (2-3)	Felt by a few indoors, especially on upper floors or while lying down.			Delicately-suspended objects may swing. Effects noticed in I are more obvious.	
III (3)	Felt by several while indoors. Similar to passing of light truck. Duration estimated.	Parked cars rock slightly.		Hanging objects may swing.	
IV (3-4) Small earthquake	Felt by many indoors, a few outdoors, light sleepers awakened, a few frightened. Similar to passing of heavy truck or heavy object jolting and hitting wall.	Parked vehicles rock.	Wooden walls & frame creak.	Dishes, windows, doors, glassware and crockery rattle, clash, clink. Hanging objects swing. Liquids in open vessels slosh back and forth.	Rock falls may be triggered.[3]

V (4-5)	Felt by almost everybody, indoors and outdoors. Most sleepers awakened, some are frightened and run outdoors. Shaking direction estimated. Buildings tremble throughout.		Some plaster walls, and rarely, windows crack.	Small, unstable objects e.g., glassware, dishes, objects d' art are displaced, upset, broken. Pictures are skewed or thrown against wall. Doors/shutters open or close abruptly. Liquids disturbed/spill. Pendulum clocks change rate or stop/start. Hanging objects swing greatly. Slight shaking of trees and bushes.	Liquefaction threshold. Fractures over several hundred meters long on fault plane but seldom breach ground surface[3].
VI (5) Moderate earthquake	Felt by all, many are frightened and run outdoors[3]. Walking is unsteady. Some loss of life possible near epicenter.		Masonry D: plaster and brick walls crack and pieces fall.	Many small objects such as dishes, glassware, knickknacks, or books are broken or thrown off shelves. Pictures fly off walls. Heavy furniture moved, lighter pieces overturned. Small bells ring. Trees and bushes rustle and shake.	
VII (5-6)	Difficult to stand.	Drivers notice ground movement.	Masonry D damaged: cracks, falling of plaster, stucco, loose bricks/stones/tiles, cornices, parapets, and ornaments fall. Some cracks in Masonry C walls and foundations.	Hanging objects quiver. Furniture is overturned and broken. Large bells ring. Trees and bushes rustle moderately to strongly. Concrete irrigation ditches are damaged[3].	Seiche waves are produced in ponds, water can become turbid with mud[3]. Small slumps and slides along sand and gravel banks[3].
VIII (6-7) Major earthquake		Steering is affected.	Masonry C buildings may partially collapse. Some damage to Masonry B, none to Masonry A. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, tombstones, towers, elevated tanks may twist or fall. Unbolted frame houses shift on foundation, loosely attached panels are thrown from frame. Solid stone walls are cracked and broken seriously.	Branches are broken from trees. Decayed pilings are broken off[3].	Spring or well water may change flow rate, odor, turbidity, or temperature[3]. Dry wells may renew flow[3]. Cracks develop in wet ground or steep slopes[3]. Sand boils may eject small amounts of mud/sand[3].
IX (7)	General panic[3]. Extensive loss of life possible[3].		Masonry D. buildings destroyed. Masonry C heavily damaged, sometimes with total collapse. Masonry B structures are seriously damaged. General foundation and frame damage. Unbolted structures shift off foundations.	Underground pipes may be broken[3].	Conspicuous ground cracks[3]. Sand boils, earthquake fountains, sand craters occur in alluvial areas[3]. Serious damage to reservoirs. Fractures 20-30 km long breach ground surface[3].
X (7-8) Great earthquake			Most masonry and frame structures, and their foundations are destroyed[3]. Some well-built wooden buildings and bridges collapse[3]. Serious damage to dams[3].	Rails bent slightly[3]. Underground pipelines crushed or separated[3].	Serious damage to dams[3]. Large landslides are triggered[3]. Water is thrown onto banks of water bodies[3]. Lateral spreading of sand/mud occurs on beaches and flat land[3]. Fissures occur on wet banks[3].
XI (8-9)			Well-built bridges collapse due to failure of ground at pillars, footings and piles[3].	Rails are bent greatly[3]. Underground pipelines are completely out of service[3].	Ground disturbances are abundant and widespread, particularly if ground is soft and wet[3].
XII (8-9)	Lines of sight and level are distorted[3].		Damage nearly total[3].	Objects are tossed into the air[3].	Large rock masses are displaced[3]. Significant landslides are numerous and extensive[3].

Note: 1: The effects given with each intensity level are taken from Wood and Neumann (1931) and Richter (1958).

2: Approximate earthquake magnitude which may produce the intensity effects near the epicenter.

3. These criteria may be misleading as measure of the strength of shaking (Dietrich and others; 1982, Keefer, 1984).

CONSTRUCTION TYPES:

Masonry A: The building shows good workmanship using good materials, the design includes reinforcement specifically intended to withstand lateral forces.

Masonry B: The building is reinforced and shows good workmanship using good materials, but the reinforcement was not designed to withstand lateral motion.

Masonry C: The unreinforced building shows ordinary workmanship with standard materials. The building has no extreme weaknesses, like failing to tie-in at corners, but it is not designed to resist lateral forces.

Masonry D: The building is constructed of weak materials, such as adobe or poor mortar, with low standards of workmanship, and the design is weak against horizontal forces.

MODIFIED MERCALLI INTENSITY SCALE (Wood and Neumann, 1931; Richter, 1958).

The intensity of an earthquake is a subjective measure of ground shaking experienced by humans and damage to their artifacts. The Modified Mercalli Intensity (MMI) scale ranges from I, shaking rarely felt, to XII, shaking which causes total damage. Ground shaking is the acceleration and velocity of particles at a site during an earthquake. It is dependent on: 1) seismic source characteristics such as peak acceleration, duration, and spectral components of seismic waves; 2) the attenuation of seismic wave amplitude and spectral filtering during travel from the earthquake focus to the site; 3) ground conditions at the site including the depth of the water table and the thickness, mineralogy, and textural composition of unconsolidated deposits; 4) the design, workmanship quality, and age of construction at the site; and 5) the expertise of people experiencing the shaking, and the investigator.

The MMI scale has been revised several times since Mercalli (1902) originally revised the 1883 Rossi-Forel Intensity Scale to include recent technological advances, such as tall buildings, motorized vehicles, and underground pipelines. The U.S. Coast and Geodetic Survey uses the 1931 version of the MMI scale which was amended by Wood and Neumann (1931) to conform to California conditions. The U.S. Geological Survey uses the 1956 version of the MMI scale which includes construction types characterized by Richter (1958). Simon (1976) believes that the 1956 MMI should be updated to include effects on a person resting on a waterbed and interruption of lifelines, such as telephone, water, gas, and electricity.

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Endowment

The **Allen H. James** Memorial Fund is a permanent endowed fund at Department of Applied Earth Sciences, Stanford University. James was a practicing geologist and mining engineer in Salt Lake City for many years. The fund to assist geology students is tax deductible. Contact Dr. Marco Einaudi, School of Earth Sciences, Stanford University, Stanford, CA 94305.

Obituary

Wilbur Smith passed away September 3, 1988 in Tooele, Utah. He was an economic geologist whose extensive mapping and mine studies for Kennecott of the Lark Mine and the Bingham district served to define operations for many years. He retired in 1978 after dedicating 19 years to the Bingham district and helping manage a younger generation of geologists.

GREAT SALT LAKE LEVEL

Date (1988)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Apr 01	4209.55	4208.65
Apr 15	4209.40	4208.55
May 01	4209.45	4208.45
May 15	4209.35	4208.45
Jun 01	4209.10	4208.30
Jun 15	4208.95	4208.15
Jul 01	4208.70	4207.95
Jul 15	4208.30	4207.60
Aug 01	4208.05	4207.25
Aug 15	4207.60	4206.90

Source: USGS provisional records.

The Magnitude 5.3 San Rafael Swell, Utah Earthquake of August 14, 1988:

A PRELIMINARY SEISMOLOGICAL SUMMARY

by S.J. Nava, J.C. Pechmann and W.J. Arabasz
University of Utah Seismograph Stations
Department of Geology and Geophysics

On August 14, 1988, an M_L (local magnitude) 5.3 earthquake occurred in central Emery County, Utah, at 2:03 PM (MDT). The epicenter of the shock—the largest earthquake to occur in the Utah region since the 1975 M_L 6.0 Pocatello Valley earthquake—was in an unpopulated area of east-central Utah on the northwest edge of the San Rafael Swell (figure 1). The epicenter was located 20 km southeast of Castle Dale (the nearest town) and 55 km south of Price. The earthquake was felt strongly throughout central Utah (Modified Mercalli intensity V to VI), where it caused some minor damage, and was reported felt as far away as Golden, Colorado, and Albuquerque, New Mexico (U.S. Geological Survey, 1988).

Historically, the two largest earthquakes in east-central Utah were both of estimated magnitude 4.3. They occurred 70 km northwest of Moab in 1953 and 50 km east of Price in 1961. Instrumental monitoring by the University of Utah since 1962 has shown sparse seismicity in the area of the San Rafael Swell, although locally intense microseismicity characterizes coal mining areas of the eastern Wasatch Plateau to the northwest. Shocks of M_L 3.1 and 3.0 occurred within 20 km of the August 14 main shock, in 1962 and 1964, respectively. Prior to August 14, the epicentral area had not experienced any earthquakes large enough to be detected by the University of Utah's regional seismograph network since January of 1988, when a swarm of seven events ($M_L \leq 2.5$) occurred there. On August 14, six foreshocks of magnitude 1.8 to 3.8 occurred during the 65 minutes prior to the M_L 5.3 main shock. The two largest foreshocks, of M_L 2.9 at 12:58 PM (MDT) and of M_L 3.8 at 1:07 PM (MDT), were felt in nearby small towns (U.S. Geological Survey, 1988).

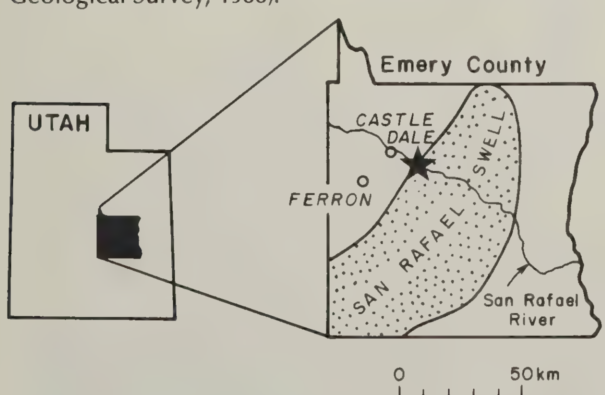


Figure 1. *Reference Map depicting the geographic location of the August 14, 1988 San Rafael Swell, Utah earthquake sequence. The star represents the location of the main shock.*

The University of Utah has located 147 earthquakes associated with the San Rafael Swell sequence that occurred from August 14 through September 30, 1988. The parameters of the five largest earthquakes of the sequence are described in table 1. Through September 30, there were 24 earthquakes of magnitude 2.0 and larger. A plot of earthquake magnitude vs time (figure 2) indicates a typical foreshock-main shock-aftershock sequence.

The nearest seismograph station at the time of the August 14 main shock was a permanent station of the University of Utah seismograph network located 20 km to the east at Cedar Mountain. Beginning the day after the main shock, the University of Utah installed five portable seismographs in the epicentral area (triangles, figure 3). Four temporary seismograph stations, directly linked to the University of Utah central recording lab in Salt Lake City, were installed on August 20 and 21 (inverted triangles, figure 3). These stations supplemented the portable seismographs until August 31, when the latter were removed. The telemetered stations continue to operate as of mid-November, 1988.

The local seismograph stations provide excellent control on the locations of aftershocks that occurred after 7:10 PM (MDT) on August 15. The locations of some of the earlier events in the sequence, particularly the focal depths, are less well constrained. For this reason, we have fixed the depth of the main shock and several events to 14 km (see table 1), a depth close to that of the deepest

TABLE 1

SAN RAFAEL SWELL, UTAH, EARTHQUAKE SEQUENCE
$M_L \geq 2.9$

DATE (1988)	ORIGIN TIME (UTC)	LATITUDE (°N)	LONGITUDE (°W)	DEPTH (km)	MAGNITUDE M_L(UU)	M_L(NEIS)	m_b(NEIS)
8/14	18:58:36.8	39°07.67′	110°50.10′	14.0R	2.9	3.5	--
8/14	19:07:58.8	39°07.51′	110°50.07′	14.0R	3.8	4.3	--
8/14	20:03:03.9	39°07.25′	110°50.28′	14.0R	5.3	--	5.5
8/15	14:50:23.5	39°07.59′	110°50.39′	14.0R	3.0	3.5	--
8/18	12:44:53.5	39°07.49′	110°50.72′	11.6	4.4	--	4.6

UTC (Universal Coordinated Time) = MDT - 6 hours

R = Restricted Focal Depth

M_L = Local Magnitude

m_b = Body Wave Magnitude

UU = University of Utah Seismograph Stations

NEIS = National Earthquake Information Service, Golden, Colorado

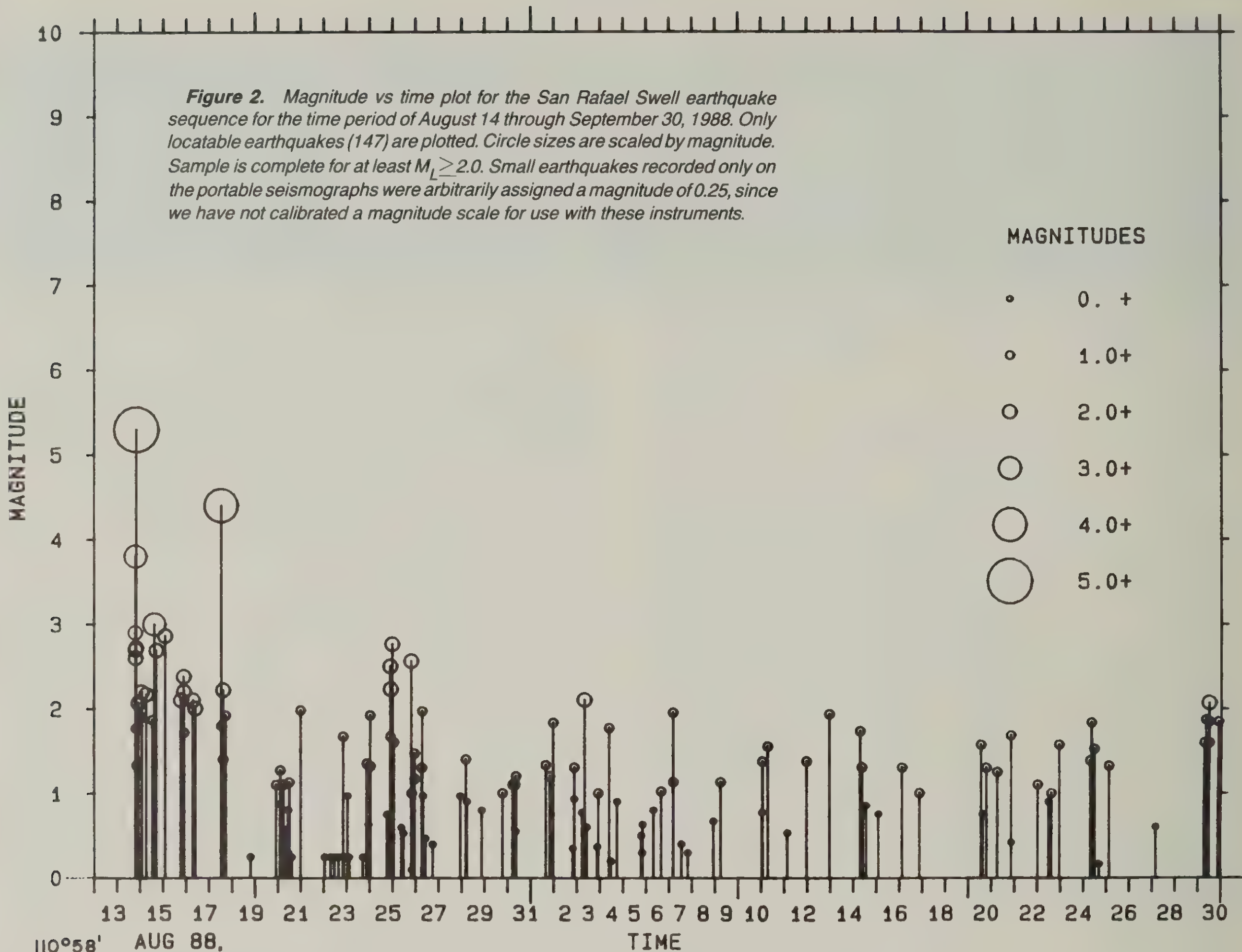


Figure 2. Magnitude vs time plot for the San Rafael Swell earthquake sequence for the time period of August 14 through September 30, 1988. Only locatable earthquakes (147) are plotted. Circle sizes are scaled by magnitude. Sample is complete for at least $M_L \geq 2.0$. Small earthquakes recorded only on the portable seismographs were arbitrarily assigned a magnitude of 0.25, since we have not calibrated a magnitude scale for use with these instruments.

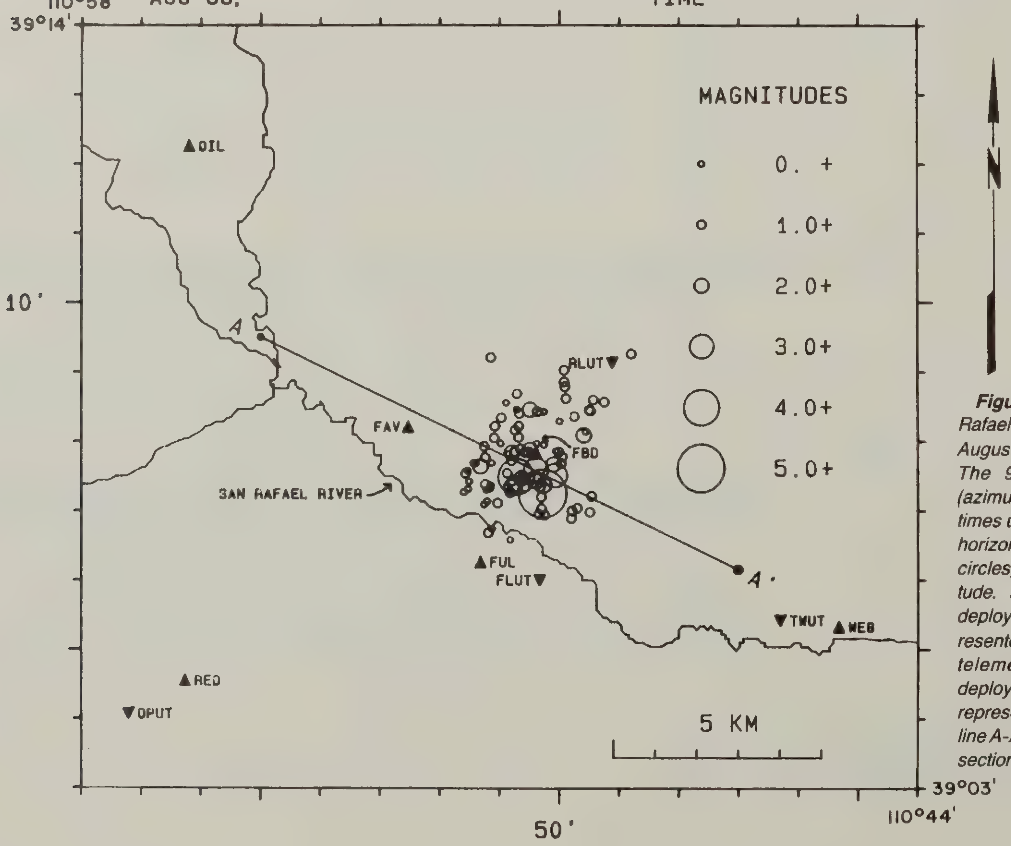
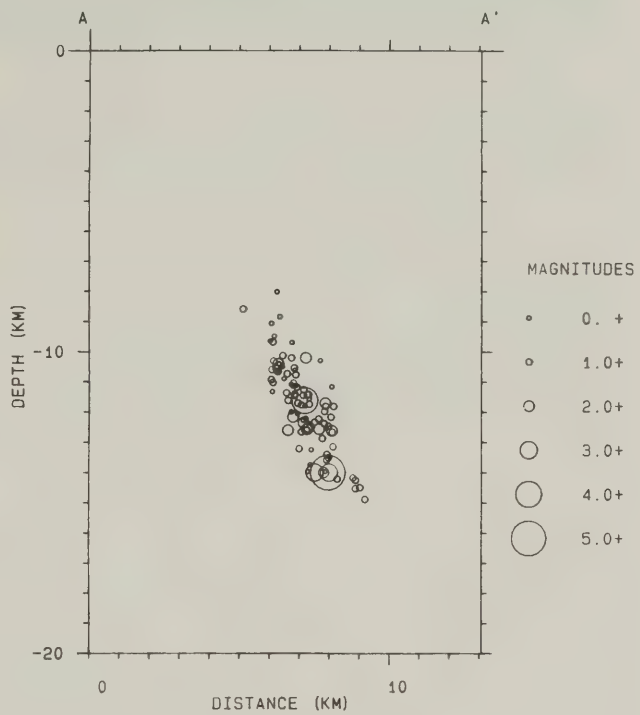


Figure 3. Epicenter map of the San Rafael Swell earthquake sequence from August 14 through September 30, 1988. The 91 best located earthquakes (azimuth gap $\leq 180°$, number of arrival times used in location ≥ 6, vertical and horizontal error ≤ 1.5 km), are plotted as circles, with the sizes scaled by magnitude. Portable seismograph stations, deployed from August 16-31, are represented by triangles, and the temporary telemetered seismograph stations, deployed from August 20 to present, are represented by inverted triangles. The line A-A' shows the direction of the cross section in figure 4.

well-located aftershocks. Figure 3 is an epicenter map of 91 of the best located earthquakes in the sequence. In map view, the earthquakes occupy a 3 x 4 km zone, adjacent to the main shock epicenter, elongated slightly in a north-northeast direction. In three dimensions, the hypocenters define an aftershock zone extending from 8 to 15 km depth and dipping 60° - 70° east-southeast, with a length along strike of 4 km and a downdip extent of 8 km.

The focal mechanism for the main shock is unfortunately not well constrained by the P-wave first motion data that we have acquired to date (figure 5). We are in the process of obtaining additional data from seismograph stations operated by other institutions, which should help to constrain the solution. The data presently available require one nodal plane to strike southeast and dip 50° - 75° southwest and the other nodal plane to strike north-northeast to northeast and dip between 40° east-southeast and 75° northwest. If the latter nodal plane is assumed to dip 60° east-southeast, parallel to the aftershock zone, then the resulting focal mechanism shows oblique normal faulting with a rake angle of -35° (solid lines, figure 5). Despite the uncertainty in the nodal plane orientations, the T axis of the main-shock focal mechanism is constrained to have a shallow plunge and an azimuth within 25° of east-west. The focal mechanism for the largest aftershock indicates oblique normal faulting on a plane that dips either to the east or southwest, and has a shallowly plunging T axis oriented N60°E-S60°W (±10°).

Figure 4. *Hypocentral cross section, with no vertical exaggeration, of the earthquakes of figure 3, taken along line A-A.' Circle sizes are scaled by magnitude.*



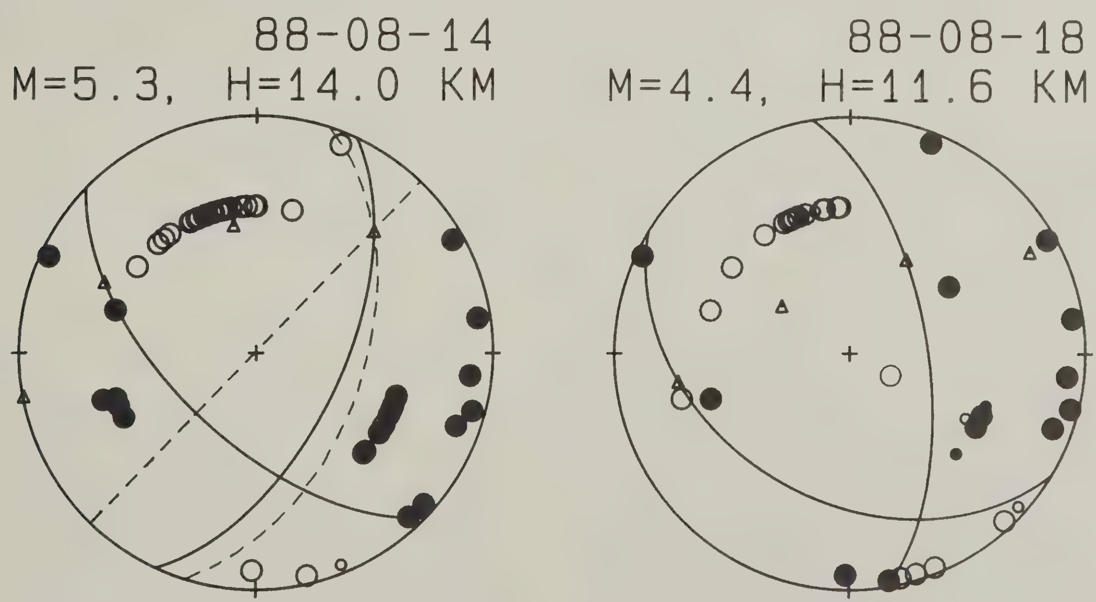


Figure 5. *Preliminary focal mechanisms for the M_L 5.3 San Rafael Swell earthquake and its largest aftershock (M_l 4.4). P-wave first motions are plotted on a lower hemisphere projection, with compressions shown as solild circles and dilatations shown as open circles. The triangles show slip vectors and P and T axes. The focal depth (H) of the main shock is not very well constrained, and was fixed at 14 km to compute the focal mechanism. The first motion plot is not very sensitive to the assumed focal depth. We have drawn our preferred solution for the main shock focal mechanism (solid lines) to have one nodal plane parallel to the aftershock zone, with a strike of 25°, dip of 60°, and rake of -35°. The dashed lines show two of the alternative orientations for the northeast-striking nodal plane that are allowed by the first motion data if the southeast-striking nodal plane is held fixed. For the aftershock, the east-dipping nodal plane has a strike of 351°, a dip of 63°, and a rake of -62°.*

The relatively deep focal depths of the earthquakes of the San Rafael Swell sequence, together with the main-shock focal mechanism, are important for attempting to correlate the earthquakes with local geologic structure. No surface faulting associated with the San Rafael Swell earthquakes has been reported, although no one, to our knowledge, has thoroughly searched the epicentral area. The fact that all of the well-located aftershocks are between 8 and 15 km in depth suggests that the earthquake rupture was confined to this depth range and did not penetrate to the surface. The apparent absence of surface faulting is consistent with a threshold magnitude of about 6.0 to 6.5 for surface faulting in the Utah region (Arabasz and others, 1987).

The depth of the San Rafael Swell earthquakes places them within Precambrian basement; gently-dipping sedimentary cover rocks of Mesozoic and Paleozoic age are about 3 km thick in this area (e.g., Neuhauser, 1988). Jurassic and Cretaceous strata in this part of the San Rafael Swell are known to have been affected by east-verging imbricate thrust faulting of Sevier-age deformational style (Neuhauser, 1988), but this shallow faulting did not involve Precambrian basement. Northwest- and northeast-trending basement fracture zones appear to provide important structural control on crustal blocks within the Colorado Plateau (Davis, 1978). Such basement faults presumably controlled the Laramide development of the San Rafael swell as a broad anticlinal upwarp with a monoclinal flexure on its southeastern flank some 65 million years ago (Davis, 1978; Stokes, 1986).

Geological maps of the San Rafael Swell (e.g., Hintze, 1980) show faults of north-northeast and northwest trend cutting Mesozoic rocks in the general vicinity of the recent earthquake activity. Data in hand suggest the association of the 1988 San Rafael Swell earthquake with buried slip on a Precambrian basement fault striking north-northeast and dipping moderately to steeply to the east-southeast. The aftershock distribution and magnitude versus fault length relations suggest that the causative fault need not be more than several kilometers long. Focal mechanisms imply a response to horizontal extension in a roughly east-west direction. This is similar to contemporary deformation inferred for the Basin and Range-Colorado Plateau transition to the west (Arabasz and Julander, 1986), but at variance with the north-northeast — south-southwest to northeast-southwest extension recently discovered to characterize the interior of the Colorado Plateau (Wong and others, 1987; Wong and Humphrey, 1988).

Earthquakes of moderate size ($M_L \leq 6.5$) are capable of causing considerable damage in urban areas, as evidenced by the M_L 5.9 Whittier Narrows earthquake that struck southern California on October 1, 1987 (Hauksson and others, 1988). The occurrence of the M_L 5.3 San Rafael Swell earthquake in an area where there are no active faults mapped at the surface and where historical earthquake activity has been minimal emphasizes the potential for moderate but potentially damaging earthquakes on buried faults anywhere in the Utah region—including the Colorado Plateau.

Acknowledgements— We thank Ted Olson and Allan Stevens of Snow College and Erwin McPherson, Ken Whipp, Julie Shemeta, and Mary Murphy of the University of Utah for installing and operating seismograph instrumentation in the field. Linda Hall of the University of Utah timed the records of the portable seismographs. Rick Martin of the U.S. Bureau of Reclamation, Pingsheng Chang of the U.S. Geological Survey, Joyce Wolff of Los Alamos National Laboratory and Doug Bausch of Northern Arizona University kindly supplied data from seismic networks in Colorado, New Mexico and Arizona. This research was supported by the U.S. Geological Survey, Department of the Interior, under award numbers 14-08-0001-A0265 and 14-08-0001-G1349, and by the state of Utah.

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CEM ALERT Report Summary of August 14, 1988 Earthquake in Emery County

by Jim Tingey and Fred May Ph D.
Utah Division of Comprehensive Emergency Management

The Utah Division of Comprehensive Emergency Management (CEM) responded to the moderate earthquake activity in Emery County by its usual state-to-county response procedures, and through two CEM Affected Location Emergency Response Team (ALERT) efforts, to follow-up on possible county and city damage and public needs and reaction.

INITIAL CEM RESPONSE

CEM Director Lorayne Frank was informed of the magnitude 5.3 quake by UGMS Director Genevieve Atwood who was notified by the press. Although this is not the "standard" emergency communications procedure, it probably reflects or typifies how initial notification does happen in a "real world" situation, and even how it may happen in a larger event in a more heavily populated area. The important fact is that these two high-level state officials were notified within minutes and began to respond using "standard" procedures. Lorayne Frank then contacted the following officials in the order listed, who took the indicated action or gave information relating to the earthquake.

Official Notified	*Action*
1. Doug Bodrero, Deputy Commissioner, Utah Department of Public Safety.	Reports to Commissioner of Public Safety who then may contact the Governor. Records information on damage and resources needed.
2. University of Utah Seismograph Stations	Magnitude, location of epicenter, any reported damage.
3. Dave Levanger, Carbon County Emergency Director	Reported on damage, down utilities and was to report back on possible mine problems.
4. Lamar Guymon, Emery County Sheriff/Emergency Director	Report damage to towns, mines, power facilities.
5. Utah Power and Light	Report on operating mines and power facilities in Emery and Carbon counties.
6. Gene Surzenegger, Utah DOT Assistant Director	Report on condition of roads, any damage for possible DOT response.
7. Bob Morgan, Utah State Engineer	Report on conditions of dams which were in the risk area.

Note: The state engineer in coordination with Lorayne Frank of CEM and Doug Bodrero of Public Safety arranged for the use of a fixed wing aircraft to make an immediate examination of the dams and reservoirs. Two dams had "on ground" visits, Millsite and Grass Trail. Others surveyed by air in the Green and Colorado drainages were:

Smith Reservoir
Lower Gooseberry Reservoir
Fairview Lakes
Cleveland Reservoir
Electric Lake (checked by UP&L)
Miller Flat
Scofield Reservoir (checked by BOR)
Duck Fork Reservoir
Farron Reservoir
Wrigleys Spring Reservoir
Rolfson Reservoir
Joes Valley Reservoir (checked by BOR)

The Thistle slide was also surveyed by air.

Reservoirs surveyed in the Sevier River drainage were:

- Nine Mile Reservoir
- Gunnison Reservoir
- Sevier Bridge Reservoir
- Chicken Creek Reservoir
- Mona Reservoir and Huntington North (BOR)

CEM requested reports on damage or any effects to mines, road, dams, bridges or personal property. Reports of any injuries resulting from the initial ground motion or secondary effects such as rock fall were also requested. No affirmative reports were received, although later reports indicated some minor damage in Castle Dale.

This moderate event provided a good test of the response mechanism of the state and proved the value of written and exercised emergency notification and reporting procedures.

The morning after the event CEM ALERT members Jim Tingey and Bill Damery accompanied a University of Utah Seismograph Stations team to install portable seismographs in the epicentral area east of Castle Dale. Examination of this area provided only inconclusive evidence of recent seismic-related rockfall and liquefaction cracks in the Cottonwood, Huntington Creek and San Rafael drainages.

Two pieces of video tape footage taken during the earthquake were acquired by CEM ALERT and are available through the CEM Earthquake Preparedness Program.

Subsequent to their first "on site" visit CEM ALERT contacted the major insurance agencies in the area. Surprisingly, although no reports of serious damage had been reported to local government officials, the insurance companies had received reports of over 25 claims. Many of the insurance representatives were out inspecting damage the week of the earthquake. A second CEM ALERT field survey was planned along with a public meeting on earthquake awareness and preparedness focusing on citizen concerns surrounding the Sunday, August 14, 1988 event. The public meeting was held the evening of August 22nd at the Emery County Courthouse in Castle Dale. Notification of the meeting was put in both the Carbon County and Emery County newspapers. The CEM ALERT group consisted of Earthquake Planning Coordinator Jim Tingey, Bureau Chief DeeEll Fifield, Hazard Mitigation Officer Dr. Fred May, Planning Geophysicist Bill Damery, and Intern Steve Pratt.

The meeting and damage survey was coordinated through the Emery County Emergency and Sheriff's offices. Much non-structural damage was reported, such as broken dishes, overturned bookcases and falling ceiling tiles. The most common structural problems reported were damaged chimneys. A maximum Modified Mercalli Intensity of VI was indicated by damage in Castle Dale, Orangeville and Ferron.

The quake produced impressive dust clouds from numerous rock falls in nearby canyons. It shook bricks off some chimneys and produced cracks in foundations, patios, and driveways. In residences, some furniture shifted and some dishes fell out of cabinets, and one large front window was broken. In a nearby church, earthquake waves were seen moving through tiled-concrete hallway floors. A paradox was found in a Castle Dale ceramics shop where nearly all delicate ceramic pieces hanging over the edge of a long shelf did not fall off. No one sustained a loss of electrical power, and large coal-fired power plants in the area continued to operate with only minor interruption. No one lost water pressure and wells continued functioning. All fuel lines remained intact. A few people temporarily lost the use of their telephones.

The public meeting attracted over 150 people from Emery and Carbon Counties. The purpose of the meeting was to educate locals about simple earthquake mechanisms, regional tectonics, scientific observations regarding the August 14 quake, and to gather response through two written surveys. A lengthy question and answer session followed the formal presentations. During the question and answer session, several long-time residents related their knowledge of the epicentral area including location of faults and mines not shown on geological maps displayed at the meeting. Miners working in mines along the Wasatch Plateau to the west said they did not feel any motion during the time of the quake. Several others related interesting stories of their response. Many questions related to concern over the reason no warning was issued even though minor seismic activity had been recorded since January, and the reason why studies have concentrated on the Wasatch Front.

The results of the area informational surveys were interesting. For example most surveyed:

a) felt that earthquake scientists do know enough about earthquake threat to cause government to take steps to protect them.
b) *would not* sue anyone if a loved one were killed in an earthquake.
c) *do not* feel that a supreme being causes major earthquakes.
d) *do not* feel adequately prepared for a major earthquake.
e) *do not* feel that local governments are prepared for a major earthquake.
f) do feel that government should do more to inform them about earthquake threat and risk.
g) *did* hear a loud noise before feeling ground motion.

Additional results:

a) 52 percent were at home, 25 percent were in church.
b) 25 percent had dishes and objects fall out of cupboards.
c) 20 percent had minor cracks in foundations, patios, driveways, etc.
d) 14 percent had bricks fall from chimneys or walls.

For information contact: Jim Tingey or Dr. Fred May, Utah Division of Comprehensive Emergency Management, 1543 Sunnyside Ave., Box 8136, Salt Lake City, Utah 84108-8136. Telephone (801) 533-5271.

ITEMS OF INTEREST

Call For Papers

A call for papers for U.S. Geological Survey Professional Paper *Assessing Regional Earthquake Hazards and Risks Along the Wasatch Front, Utah, Part B* was issued in early December, 1987. Manuscripts will be accepted until January 1, 1989. Persons interested in submitting papers, and who seek information regarding style and peer review should contact:

Paula Gori
U.S. Geological Survey
905 National Center
Reston, VA 22092
(703) 648-6707

Those wishing to present papers at the *World Gold '89 — Gold Forum Technology & Practices* meeting to be held October 22-25, 1989 are invited to submit a 200-word abstract. Held at Bally's Hotel, Reno, Nevada, the meeting is sponsored by Society of Mining Engineers and The Australasian Institute of Mining and Metallurgy. Submit abstracts to:

Meetings Department—World Gold '89
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550

The Western Surface Coal Mining meeting is calling for papers for the May 3-5, 1989 meeting in Gillette, WY. Deadline for abstracts is October 15th. Contact:

Meetings Department, SME
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550

Utah Geological Association requests papers for a 1989 conference/field trip focusing on geology and hydrology of hazardous-waste, mining-waste, wastewater or brine-disposal, and waste-repository sites in Utah. Tentatively scheduled for October 6-7 in Salt Lake City, the meeting will have papers printed in The Proceedings Guidebook and given orally. Brief descriptions are due December 1 and drafts by April 1, 1989. Contact:

Joseph S. Gates
U.S. Geological Survey, WRD,
1745 W. 1700 S., Salt Lake City, UT 84104.
(801) 524-4073 or (801) 524-4244.

A call for papers has been issued for the 1990 Society of Mining Engineers Annual Meeting, February 26-March 1, Salt Lake City, Utah. The deadline for receipt of preliminary abstracts is February 1, 1989.

To receive details of the proposed session topics, contact:

Meetings Department
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550, Telex: 881988, Fax: 303-973-3845.

Meetings

February 13-14, 1989 Geophysics of the Rocky Mountains. Meeting in Golden, CO. Contact Front Range AGU Service Center, Box 18-P, Denver, CO 80218. (303) 831-6338.

February 27-March 2, 1989 Society of Mining Engineers 1989 Annual Meeting will be in Las Vegas, Nevada at the Las Vegas Convention Center. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162, (303) 973-9550.

February 27, 1989 118th AIME Annual Meeting. AIME Will meet at the Las Vegas Hilton.

May 3-5, 1989 Western Surface Coal Mining meeting, Gillette, Wyoming. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO

July 9-19, 1989 28th International Geological Congress, Washington, D.C. For information contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001, (703) 648-6053.

September 10-14, 1989 Editing Into the Nineties. Joint meeting at the Westin Hotel in Ottawa, Canada of Council of Biology Editors, European Assoc. of Science Editors, Assoc. of Earth Science Editors, and National Research Council of Canada. Contact Ken Charbonneau, Executive Secretary, National Research Council of Canada, Ottawa, Canada K1A OR6, (613) 993-9009.

Books & Papers

Geologic Map of Arizona; new release from the Arizona Geological Survey. This new map, compiled by Stephen J. Reynolds, is at a scale of 1:1,000,000 and incorporates a multitude of new data based on more detailed geologic mapping. It is a marked improvement over the 1969 version in the treatment of the Basin and Range and Transition areas, reflecting new mapping and new concepts.

Available from Arizona Geological Survey
845 N. Park Avenue #100
Tucson, AZ 85719.

DELINEATION OF LANDSLIDE, FLASHFLOOD, AND DEBRIS FLOW HAZARDS IN UTAH: PROCEEDINGS OF A SPECIALTY CONFERENCE (D.S. Bowles, editor), General Series G85-3, from Utah Water Research Laboratory, Utah State University, 1985. A collection of papers and abstracts from the conference with some valuable models and information.

MINERAL RESOURCES OF THE BULL MOUNTAIN WILDERNESS STUDY AREA, GARFIELD AND WAYNE COUNTIES, UTAH, by R.F. Dubiel et al., Bulletin 1751-B, U.S. Geological Survey.

BASIN CONTOURS OF THE NORTHERN SECTION, GREAT SALT LAKE DESERT, UTAH, by W.H. Chapman and W.L. Sappington, 1:96,000, 1988, Open-File Report 86-0009, U.S. Geological Survey.

A VIBRATION STUDY OF THE ARCHEOLOGICAL RUINS, HOVENWEEP NATIONAL MONUMENT, UTAH-COLORADO, BY K.W. King and S.T. Algermissen, 1988, Open-File Report 87-0181, U.S. Geological Survey.

PRELIMINARY GEOLOGIC ANALYSIS OF THE TAR SANDS NEAR SUNNYSIDE, UTAH, by C.J. Schenk and R.M. Pollastro *in* Exploration for heavy crude oil and natural bitumen (R.F. Meyer, editor), 1987, AAPG studies in Geology 25.

RECENT USGS GEOLOGIC MAPS cover Hamlin Valley and Escalante Desert (I-1774), Pine Valley area in Beaver and Iron Counties (I-1794), Indian Peak Range in Beaver and Iron Counties (I-1795), and the southern Mountain Home and northern Indian Peaks Ranges in Beaver County (I-1796).

A TRACE OF DESERT WATERS: THE GREAT BASIN STORY by S.G. Houghton, 1986, Howe Brothers of Salt Lake City. A personal overview of the geography, geology, and hydrology of The Great Basin focusing strongly on the ancient lakes (such as Lake Bonneville) and their remnants (Great Salt Lake). An excellent and personable study of water and the Great Basin.

IN THE FOOTSTEPS OF G.K. GILBERT — LAKE BONNEVILLE AND NEOTECTONICS OF THE EASTERN BASIN AND RANGE PROVINCE, Michael N. Machette, editor. This GSA field trip guide for the GSA centennial meeting held October 31 should be a must to anyone interested in Lake Bonneville, neotectonics associated with the lake and the Wasatch fault and, of course, Gilbert and his exemplary work.

The trip on Oct. 28, 29, and 30, led by Mike Machette (USGS, Denver) and Don Currey (Univ. of Utah, Salt Lake), covered much of the northern Wasatch front on the first day while exploring the Lake Bonneville cycles and faulting along the Wasatch. Day 2 explored the Old River Bed west of Salt Lake City, the Stockton Bar, and Stansbury Island. The central Wasatch front was the focus of Day 3, exploring various lake cycles, trenching sites, and the Dry Creek area. 120 pages, Utah Geological and Mineral Survey, Misc. Pub. 88-1.

GEOLOGY OF THE TULE VALLEY, UTAH 30 x 60-MINUTE QUADRANGLE, by Lehi F. Hintze and Fitzhugh D. Davis. The Tule Valley quadrangle is located in western Millard County, Utah. It features the eastern portion of the north-south-trending Snake Valley bounded on the east by the Confusion Range. Central to the quandrangle is the Tule Valley which is flanked by the Confusion Range on the west and the House Range on the east. The eastern portion of the map includes portions of Sevier Desert and Lake, Whirlwind Valley, and Little Drum Mountains. Lithologies present in the valleys include floodplain deposits, alluvium, playa and deltaic muds, eolian sediments, marsh deposits, mass movement deposits, and lacustrine features.

Geologic units in the Confusion Range are predominantly Permian, Pennsylvanian, Mississippian, and Devonian age rocks. Older Paleozoic rock types (Silurian, Ordovician, and Cambrian) are found in the House Range along with Mesozoic extrusive lithologies. Tertiary volcanics dominate the Little Drum Mountains. UGMS Open-File Report 134.

GEOLOGY AND MINERAL POTENTIAL OF THE ANTELOPE RANGE MINING DISTRICT, IRON COUNTY, UTAH, by Michael A. Shubat and W. Skip McIntosh. The Antelope Range Mining District is twenty miles west of Cedar City, Utah in the west-central portion of the Antelope Mountain Range. The district is situated on a volcano-tectonic boundary that has been active since the Late Cretaceous. Prospecting in the southern part of the district began in the 1870s. The first shaft was sunk in the early 1900s and exploration has continued intermittently until the present.

Neogene extensional thrust faulting formed northwest-striking faults and fractures that became the structural hosts for epithermal base and precious metal mineralized veins. The date for mineralization and hydrothermal alteration is approximately 8.5 million years and it is related to rhyolitic and dacitic volcanism. Factor analysis results of geochemical data indicate that at least two episodes of mineralization occurred in the district. Geochemical anomaly and precious metal anomaly maps for various vein systems are included in the report. Area stratigraphy includes Mid- to Late Jurassic marine sediments (Carmel Formation), fluvial, braided stream sediments of the Iron Springs Formation, and ash-flow tuff of the Isom Formation and Quichapa Group.

Two plates at 1:24,000 accompany the report: the geologic map and hydrothermal alteration map. UGMS Map 108 (Geologic map of the Silver Peak quadrangle, Iron County, Utah, by Shubat and Mary A. Siders) covers all but a small portion of the district and is a useful companion piece to the report. UGMS Bulletin 125.

ACID NEUTRALIZING CAPACITY MAP OF UTAH by William F. Case. The acid neutralizing capacity (ANC) map of Utah and its accompanying report is a product of (1) the Utah Division of Environmental Health, Bureau of Air Quality endeavoring to determine areas in the state that are sensitive to acid deposition and (2) The Utah Geological and Mineral Survey's efforts to show where geologic materials will not buffer the acid deposition.

Chemical bonding of water with carbon dioxide in the air or by-products from fossil fuel combustion, a saline lake deposit, or lightning can cause precipitation to be as acid as vinegar. This precipitation, along with the settling of airborne chemicals, causes increased amounts of acidity in Utah's surface waters. Ultimately, the acidity of Utah's lakes and rivers is determined, in part, by the neutralizing properties of the geologic materials through which acid deposition moves. The map included in this report is designed as an overlay for the 1980 Geologic Map of Utah by Lehi Hintze. It shows the regional distribution of ANC classes as outlined in the report. Utah Geological and Mineral Survey Open-File Report 132.

AN OVERVIEW OF LANDSLIDE INVENTORIES PREDOMINANTLY OF NORTH AMERICA by Sandra N. Eldredge. This report summarizes 38 landslide inventories, mostly from the U.S. and Canada. The 1986 survey shows the diversity of landslide inventories with emphasis on small-scale work at the state level. Objectives, methodologies, map scales, terminology, products and data, and the relative successes of these are discussed with a view to improving the informational quality and collection methods of future surveys. UGMS RI 217.

QUATERNARY GEOLOGY OF THE BLACK ROCK DESERT, MILLARD COUNTY, UTAH by Charles G. Oviatt. Tertiary and Quaternary basalts, rhyolite domes, volcanic vents, lacustrine and alluvial deposits, and thin eolian sands dominate the surface of this project, based on an area covered by twelve 7½-minute quadrangle maps. The study area is in Millard

County and encompasses the southern extension of the Sevier Desert between the Cricket Mountains and the Pahvant Range.

Radiocarbon age dates from samples illustrate relationships between local eruptive events and Lake Bonneville historical levels. Regional structural features include Quaternary faults and the doubly plunging Cove Creek Dome anticline.

Part of an ongoing set of studies on the Quaternary geology of western Utah, this report is a COGEOMAP product (see Survey Notes v. 21, no. 2-3,), available as UGMS Open-File 128.

UGMS Personnel

Annona Youngdell, long-time secretary for the Mapping and Economic sections, moved to the State Board of Education. We hope they realize the jewel they've received. She is replaced by **Jean Muller,** most recently with the school board in Kemmerer, Wyoming.

Barry Solomon, of Battelle's Project Management Division where he was geotechnical advisor, begins work in the Applied section and brings extensive experience in oil shale, and nuclear power plant siting.

Plans for more schooling have drawn **Jackie Ledbetter** from her work as the UGMS Salesperson. Best of luck — 8 to 5 now becomes 8 to midnight.

Robert W. Gloyn has accepted the position of Geological Manager for the Economic Geology Program at the UGMS. Twenty years of varied exploration and production experience comes into play, and his work with a broad spectrum of commodities and deposit types will certainly be useful in our evaluation of Utah's resources. He has recently worked with BHP International and with Getty Oil for many years.

Congratulations to **Grant Willis** who had a photograph accepted for the GSA geologic photo album which should be coming out in time for the annual meeting.

Bob Klauk, geologist in the Applied Section for many years, has opted to work for Warzyn Engineering, Inc. in Novi, Michigan. Going back to renew his acquaintance with *REAL* winters!

And we'll have to take into account the loss of **Gwen Anderson**— the only accounting officer we've known who smiles all the time. She's off to the State's Administrative Services to help them along.

Carolyn Olsen, our curator for the Sample Library, was in a serious traffic accident on the last day of June. We are happy to report she is doing very well at her home in Bountiful, and we are anxious for her complete recovery.

New Publications

Open-File Reports

OFR-128 Quaternary geology of the Black Rock Desert, Millard County, Utah, by Charles G. Oviatt, 53 p., 1 pl. 1:100,000, 1988 ... available for public inspection at the UGMS Library.

OFR-129 Causes of shallow ground-water problems in part of Spanish Valley, Grand County, Utah, by Robert H. Klauk, 46 p., 1988 .... $4.00

OFR-130 Geologic map of the Antelope Peak quadrangle, Iron County, Utah, by S.K. Grant and P.D. Proctor, 32 p., 1 pl. 1:24,000, 1988 ... available for public inspection at the UGMS Library.

OFR-131 Sample Library Catalog, by UGMS staff, 374 p. ... available for public inspection at the UGMS Library; sections available through the Sample Library Curator.

OFR-132 Acid-neutralizing capacity map of Utah, by William F. Case, 9 p., 1 pl. 1:500,000, 1988 .... $4.50

OFR-133 West-central Kane County state lands evaluations for State Lands and Forestry, by Hellmut H. Doelling, 517 p., 1988 .... $51.00

OFR-134 Geology of the Tule Valley 30 x 60 minute quadrangle Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 33 p., 1 pl. 1:100,000, 1988 ... available for public inspection at the UGMS Library.

OFR-136 Preliminary geology of the Red Knolls 7.5-minute quadrangle, Millard County, Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 12 p., 1 pl., 1:24,000, 1988 ... available for public inspection at the UGMS Library.

OFR-137 Geologic map of the Long Ridge 7.5-minute quadrangle, Millard County, Utah, by Lehi F. Hintze and Fitzhugh D. Davis, 11 p., 1 pl., 1988 ... available for public inspection at the UGMS Library.

Report of Investigation 217 An overview of landslide inventories predominantly in North America, by Sandra Eldredge, 98 p., 1988 .... $5.25

Miscellaneous Publication 88-1 In the footsteps of G.K. Gilbert-Lake Bonneville and neotectonics of the eastern Basin and Range Province, guidebook for field trip twelve, Geological Society of America annual meeting, 120 p., 1988 .... $8.50

Miscellaneous Publication 88-2 Geology and Antelope Island, by Hellmut H. Doelling and others, 20 p. $1.50

Bulletin 125 Geology and mineral potential of the Antelope Range Mining District, Iron County, Utah, by Michael A. Shubat and W. Skip McIntosh, 26 p., 2 pl., 1:24,000, 1988 .... $6.50

Map 43 Physiographic subdivisions of Utah, by W.L. Stokes, 1 pl., 1:2,500,000, 1977 (reprint) $1.00

Map 111 Flood hazards from lakes and failures of dams in Utah, by Kimm M. Harty and Gary E. Christenson, 8 p., 1 pl., 1:750,000, 1988 .... $6.00

Map 55-C Ground-water resources of the southern Wasatch Front, Utah, by Don Price and Loretta S. Conroy, 6 p., 3 pl., 1:100,000, 1988 .... $6.00

Map 55-D Mineral resources of the southern Wasatch Front, Utah, by Fitzhugh D. Davis with petroleum resources by Floyd C. Moulton and Raymond L. Kerns, Jr., 17 p., 2 pl., 1:100,000, 1988 .... $6.00

These Prices Do Not Include Postage or Utah Sales Tax

UTAH EARTHQUAKE ACTIVITY

by James C. Pechmann

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS, DEPARTMENT OF GEOLOGY AND GEOPHYSICS

January through March 1988

Figure 1 shows the epicenters of 157 earthquakes located by the University of Utah Seismograph Stations within the Utah region during the three-month period January through March 31, 1988. The seismicity sample includes 51 earthquakes of magnitude 2.0 and greater and two earthquakes of magnitude 3.0 and greater.

The largest earthquake during the report period, and the only one reported felt, had a local magnitude (M_L) of 3.5 and occurred on January 2 on the southern border of Utah, 30 km west of Kanab. This earthquake was felt at Rockville, Springdale, and Virgin, Utah, and at Fredonia, Arizona.

Clusters of earthquakes occurred at five localities labeled on the map:

(1) a cluster of 10 aftershocks (coda magnitude (M_C) $\leq$ 1.6) of an M_L 2.7 earthquake that occurred near the Utah-Idaho border on December 11, 1987;

(2) 72 aftershocks ($M_L \leq$ 3.1) of the 1987 Lakeside earthquake sequence west of the Great Salt Lake, which included 8 shocks of M_l 3.8 to 4.8 during September and October of 1987;

(3) 26 seismic events of $M_C \leq$ 2.5 located 40 km southwest of Price in an area of active underground coal mining;

(4) a swarm of 7 earthquakes of $M_L \leq$ 2.5 that occurred 50 km south of Price between Janauary 14 and 20; and

(5) seven earthquakes ($M_C \leq$ 1.7) 40 km west of Richfield, representing a continuation of small magnitude activity that began in this area in December 1987.

The UGMS Sales Office carries printed catalogs of earthquake information collected by the University of Utah Seismograph Stations, as listed below

Earthquake Studies in Utah, 1850 to 1978, edited by Walter J. Arabasz, Robert B. Smith and William D. Richins, 1979, 552 pages, spiral bound; this is the catalog of the University of Utah Seismograph Stations as well as several earthquake-related papers.
Available as MP87-7 .... $28.00.

Earthquake data for the Utah region, by W.D. Richins and others (July 1, 1978 to December 31, 1980), October 1981, 127 pages, UGMS Miscellaneous Publication F-1 .... $5.00

Earthquake data for the Utah, region, January 1, 1981, to December 31, 1983, by W.D. Richins, and others, 111 pages, 6 figures, 4 tables,
UGMS Miscellaneous Publicaton F-2 .... $5.00

Earthquake data for the Utah region, January 1, 1984 to December 31, 1985, by E.D. Brown, and others, 83 pages, 1986,
UGMS Miscellaneous Publication F-3.............. $5.00

April through June 1988

During the three-month period April 1 through June 30, 1988, the University of Utah Seismograph Stations located 87 earthquakes within the Utah region (see figure 2). Of these earthquakes, 32 had a local magnitude (M_L) or coda magnitude (M_C) of 2.0 or greater, four had a magnitude of 3.0 or greater, and one was reported felt.

Aftershock activity from the 1987 Lakeside sequence west of the Great Salt Lake (M_L 4.8; location L on map) has now decreased to a very low level. Only two aftershocks—one of M_C 1.5 on May 6 and one of M_C 2.0 on June 14—were located in the Lakeside area during the report period. For comparison, 72 aftershocks, including 10 of magnitude 2.0 or greater, were located in the Lakeside area during the first three months of 1988. Only the comparison of the numbers of magnitude 2.0 or greater aftershocks can be considered reliable because the earthquake detection and location capability of the network in the Lakeside area deteriorated after late March. This deterioration was due to intermittent failures of the four temporary stations installed in this area in October 1987 to supplement the coverage of the permanent network stations. Aftershocks of magnitude 2.0 and greater in the Lakeside area can be readily detected and located using only the permanent network stations, although the locations are much less accurate without the local station coverage.

The two largest earthquakes during the report period occurred twelve minutes apart on May 22, but 350 km away from each other. The first was an M_L 3.6 event that occurred 10 km west of the Utah-Nevada border at 1:10 PM MDT. The second was an M_C 3.8 earthquake at 1:22 PM MDT, located 10 km south of the Utah-Arizona border and 45 km WSW of Kanab. The other two earthquakes of magnitude 3.0 or greater were an M_L 3.3 event north of the Great Salt Lake on May 11 and an M_C 3.0 earthquake 45 km SW of Price on May 4. The earthquake southwest of Price was the largest of 11 earthquakes that occurred in this area during the report period. An earthquake of M_C 2.2 on June 13, located 10 km SE of Richfield, was reported felt in Richfield.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations, Salt Lake City, Utah 84112; telephone (801) 581-6274.

In addition, the UGMS carries:

Reprints of the Seismic Safety Advisory Council's Reports. This series of reports was originally prepared in 1977-81 to provide assessment of various public facilities such as office buildings, schools, hospitals, utilities, dams and water supplies, and to give recommendations for risk reduction measures, such as building codes, in the event of damaging earthquakes.
Three volume set $30.00

All prices quoted are over-the-counter prices. For prices plus mailing costs, please contact the UGMS at 581-6831.

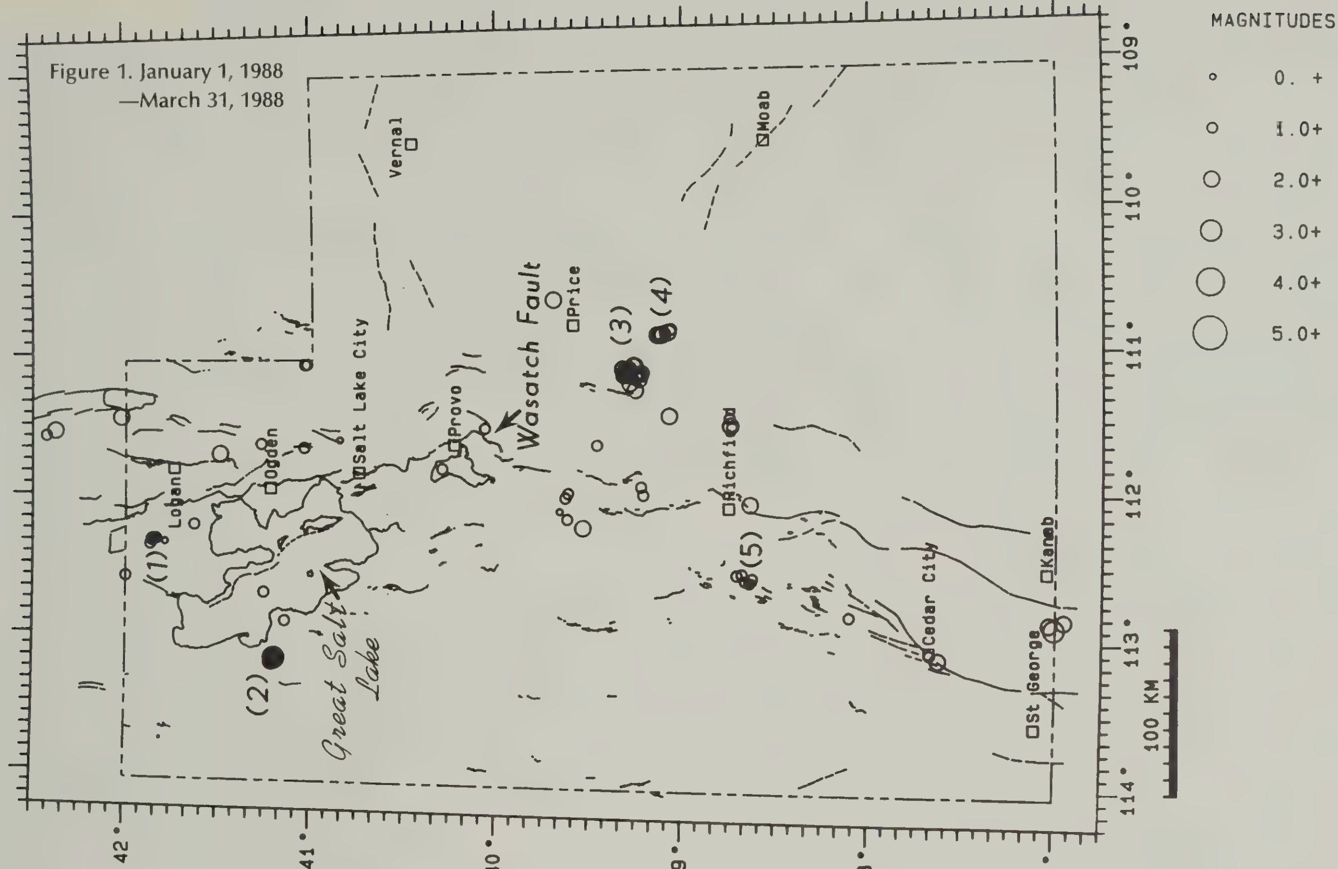

Figure 1. January 1, 1988
—March 31, 1988

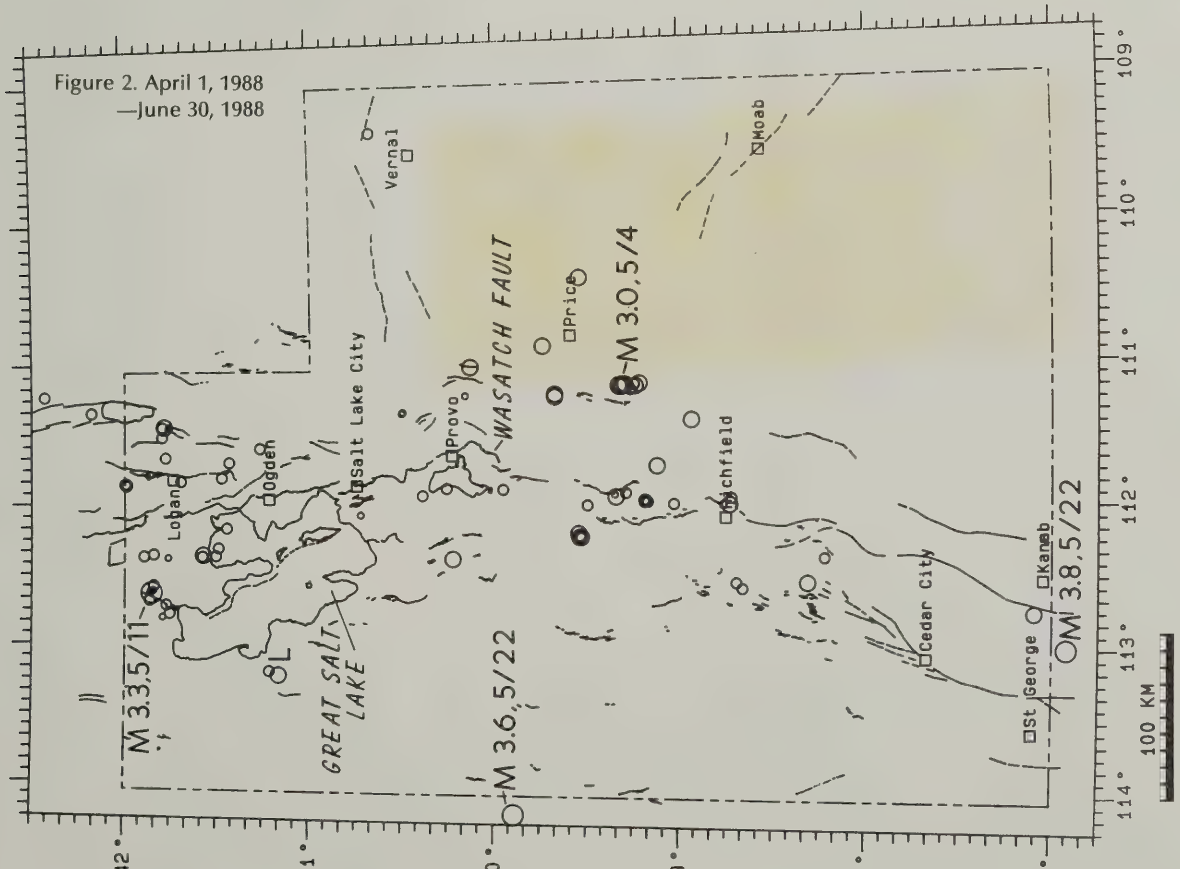

Figure 2. April 1, 1988
—June 30, 1988

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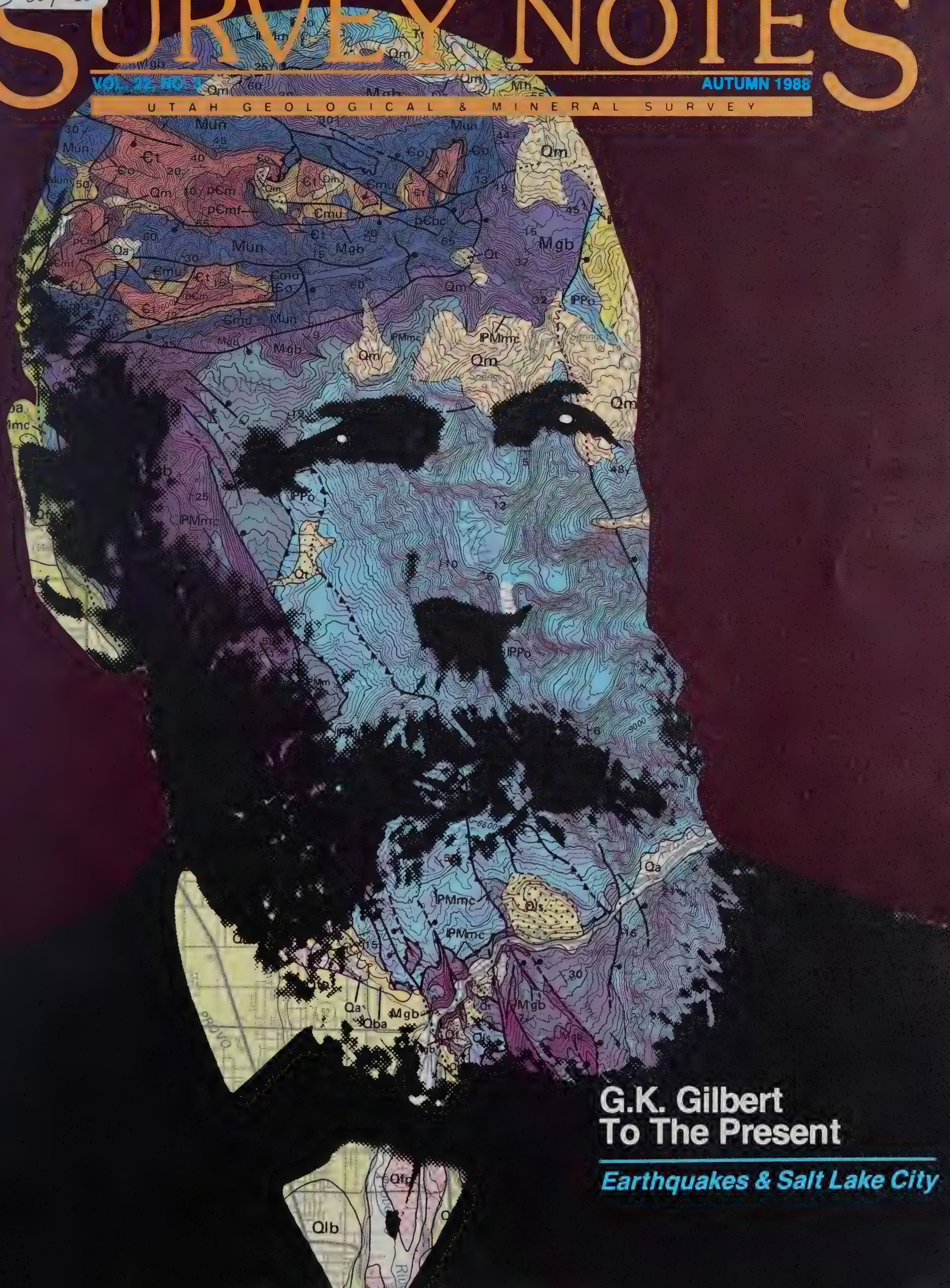

G.K. Gilbert To The Present

Earthquakes & Salt Lake City

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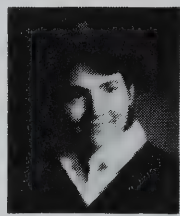


FROM THE DIRECTOR'S CORNER

In the lead article in this issue of Survey Notes William R. (Bill) Lund describes one facet of the Wasatch Front Earthquake Hazard Reduction Program and how he and other scientists are building on the pioneering work of G.K. Gilbert. One hundred five years ago Gilbert warned Salt Lake City residents of the earthquake hazard they faced and told them that the adobe houses in which many of them lived were particularly vulnerable to damage in an earthquake. Gilbert's conclusions on the earthquake threat to Salt Lake City were based on his understanding of the geology of the region and his observations of the effects of a major earthquake in a similar geologic setting at Lone Pine, California. Today, Bill and other scientists working on the earthquake hazard on the Wasatch Front still must rely on their own and their predecessor's geologic observations and extrapolate the effects of earthquakes in other areas to our conditions here.

Understanding of the earthquake hazard in Utah changed little in the years following Gilbert's warning. A major earthquake in Hansel Valley in 1934 did considerable damage along the Wasatch Front and increased public awareness, but it was not until the 1970s that major new studies were undertaken to better define the earthquake hazard. The work described by Bill is part of a highly successful cooperative program between the U.S. Geological Survey (USGS) and the Utah Geological and Mineral Survey (UGMS) that began in 1983. Under this program several millions of dollars, mostly from the National Earthquake Hazards Reduction Program (NEHRP), have supported research by scientists from the UGMS, USGS, the University of Utah, Utah State University, Brigham Young University, and several other universities and private firms.

The contrast between the work done by Gilbert in the last century and the work being done today is profound. Gilbert, working largely alone, covered most of northern Utah in a few months with little more than surveying instruments and camping gear, using horses and mules for transportation; he relied on his own observations of the geology exposed on the land surface and rarely spent more than a few hours at a location. Bill Lund's work involves the excavation of long trenches where he spends weeks mapping a few hundred square feet of trench wall. The work, although less costly than most other detailed exploration, is expensive compared to Gilbert's, requires the support of specialists in age dating, and must be interpreted in conjunction with results from other trench studies.

The work done by Bill is only one part of the dozens of kinds of research being conducted on the Wasatch Front earthquake hazard by hundreds of individuals. When Gilbert had completed his observations, he published a few conclusions in the Salt Lake Tribune. The readers of the Tribune then had, in one easily understood document, most of what was known about the earthquake hazard they faced.

Today the situation is much different. The knowledge of the earthquake hazard is contained in the work of many researchers, much of it in a form that cannot be understood and used by the general public and decision-makers who are expected to take action to reduce that hazard.

It is important that this information be made available in forms that can be understood and used. A document summarizing the major elements of the earthquake hazard is being drafted by a group initiated by Walter Hays, Deputy Chief of Research Applica-

continued page 2

UGMS Maps Released

Flood Hazard From Lakes and Failure of Dams in Utah, by Kimm M. Harty and Gary E. Christenson.

Flood hazard from lakes and failure of dams in Utah, compiled and written as a planning guide for local governments and regulatory agencies, outlines areas of the state that are likely to experience flooding hazards due to fluctuating lake levels and dam failures. The report discusses lake level fluctuations as determined from historical records and geologic and topographic features. Also discussed are Utah's dry lakes (Sevier and Rush), lowlands or basins, flooded marsh areas, salt flats and perennial lakes.

The map and report address 63 sites for which dam failure inundation studies have been completed and the agencies conducting those studies. Although more than 1000 water-retention structures are in use in Utah, only those for which inundation studies exist are on Map 111.

Ground-Water Resources of the Southern Wasatch Front Area, Utah by Don Price and Loretta S. Conroy.

Utah Geological and Mineral Survey Map 55-C is one of a series of maps describing the geology, natural resources and hazards along the Wasatch front. This non-technical report outlines the occurrence, availability and quality of ground water in the southern Wasatch front area. Examination of ground water storage in consolidated rocks of the mountains and in unconsolidated basin fill involves characteristics of basin fill that enable water storage, general conditions of ground water occurrence and dynamics of recharge and discharge of water in the ground systems. Also mentioned, is ground water quality (dissolved solids concentrations in) and temperatures.

The map is presented in three plates. Plate 1 shows ranges of transmissivity (rate at which water moves through a unit width of an aquifer under a unit hydraulic gradient) in basin fill along the front. Plate 2 traces changes in the altitude of the potentiometric surface (level at which water stands in a well that taps one or more water bearing strata. Where none of the water-bearing strata are confined, this surface is also called the water table) over a ten year period. Plate 3, water quality, shows dissolved solids concentrations of water in basin fill and locations of thermal ground water.

Mineral Resources of the Southern Wasatch Front, compiled by Fitzhugh D. Davis with a section on petroleum by Floyd C. Moulton and Raymond L. Kerns, Jr.

UGMS map 55-D shows local rock types grouped into metamorphics, igneous extrusives, igneous intrusives, carbonates, coarse and fine grained clastics and unconsolidated sediments. Evaluation of the area's metallic mineral potential includes discussion of five mining district's, their histories, type of deposits and brief production reports. Non-metallic mineral occurrences, their distribution and uses are also outlined. Construction materials, briefly mentioned, include cement, granite, sandstone, limestone, sand and gravel.

The study area, located on the eastern edge of the Basin and Range province, partially overlaps the north-south trending Hingeline. A discussion by Moulton and Kerns traces the role that the Hingeline plays in petroleum potential of the study area. Suggested petroleum targets include deep Paleozoic and Mesozoic overthrust type occurrences and shallower Tertiary sediment accumulations in valleys bounded by listric "basin and range" faults. The authors mention the potential of undiscovered, new targets created by the unique geologic setting of the region.

FROM THE DIRECTOR'S CORNER ...
continued from page 1

tions, USGS, one of the champions of earthquake hazard reduction in Utah. This document will be presented in a January 1989 workshop to about 200 earth scientists, engineers, social scientists, planners and emergency response officials representing the many groups that have worked on the hazard or are concerned with actions to reduce the hazard. The product of this workshop will be a "consensus" document of what we know about the Wasatch Front earthquake hazard and, finally, a document which can be used by professionals.

Wasatch Front earthquake hazard researchers generally agree that our knowledge is now sufficient to begin actions which would reduce the hazard. We have essential agreement on where earthquakes will happen, how often they happen, and what the effects will be. We know that ground shaking will cause extensive damage to communities near and far from a major earthquake. We have a better understanding of surface rupture, ground failure, and hydrologic changes that will be associated with a major earthquake.

In addition, the USGS has awarded a grant to the University of Utah for Walter Arabasz, Director, U. of U. Seismograph Stations and Don Mabey, retired USGS/UGMS to prepare a book for non-earth scientists describing the Wasatch Front earthquake hazard (the "consensus" document) in non-technical terms.

This process of developing a consensus on the scientific nature of the hazard is the culmination of several years of intensive study. Continuing research will refine our knowledge of the Wasatch Front earthquake hazards, particularly the mechanism of fault rupture, distribution of ground responses, and consequences to the built environment. Earthquake hazards associated with Utah's other faults still need definition. But for the next few years the emphasis will be to significantly reduce losses from the first major earthquake to strike the Wasatch Front in historic time.

The Wasatch Fault Zone, Earthquakes and Salt Lake City: G.K. Gilbert to the Present

by William R. Lund
Utah Geological and Mineral Survey, Salt Lake City, Utah

GILBERT'S THEORY OF EARTHQUAKES IN THE GREAT BASIN

G.K. Gilbert (1843-1918) was one of the most perceptive geologists ever to work in the American West. His regional investigations of Basin and Range geology with the Wheeler Survey (1871-1874), Powell Survey (1875-1879), and U.S. Geological Survey (1879-1883) resulted in a number of scientific firsts and benchmark studies that are classics of American geologic thought. Many of his theories have withstood the test of time, notably his contributions to the understanding of mountain-building processes and earthquakes in the Basin and Range province. He was the first to recognize that faulting and not folding is the primary mechanism responsible for mountain building in the interior basins of Utah and Nevada (Gilbert, 1872, 1875). He was also the first to identify "piedmont" scarps as evidence that the mountains were the result of incremental movements along range-bounding faults during earthquakes (Gilbert, 1875, 1890, 1928; Wallace, 1980).

The Wasatch fault zone, particularly near Salt Lake City, played a major role in the formulation of Gilbert's theories about mountain building and earthquakes. Although prefaced by his disclaimer, *"that the fault scarps were at no time a leading subject of investigation,"* U.S. Geological Survey Monograph 1 has his classic description of young faulting exposed along the Wasatch fault zone, and states, *"It was at the base of the Wasatch Range that the fault scarp was first discriminated as a distinct topographic feature ..."* (Gilbert, 1890, p. 342). The fault scarps at the mouth of Little Cottonwood Canyon (figures 1 and 2) occupy a prominent place in Gilbert's field notes (Hunt, 1982), and undoubtedly were the source of many of his ideas about Basin and Range faulting. He visited Little Cottonwood Canyon twice, first in 1877 to make notes on the geology and surface-water resources of the area, and again in 1880 to spend several days mapping the geology. The importance Gilbert attached to the faults at this location is evidenced by his detailed description and geologic map of the area (figure 1) in Monograph 1.

In 1883, confident that his theories about mountain building and earthquakes were correct, Gilbert issued an earthquake hazard warning to the residents of Salt Lake City. In an article in the Salt Lake City Tribune (Sept. 20, 1883) reprinted in the American Journal of Science (1884, v. 27), he summarized his ideas and emphasized their practical application in Utah. He stated that the mountains in the Basin and Range province are uplifted in small increments along faults following the release of strain that has accumulated slowly over long periods of time, and that *"the instant of yielding is so swift and abruptly terminated as to constitute a shock"* (Gilbert, 1884, p. 50). Wallace (1980, p. 38) points out that, given the current understanding of how earthquakes are generated, Gilbert's reasoning relating mountain building to earthquakes is *"so modern that, in 1980, it is difficult to understand why, once stated, the concept would not have been generally accepted and become a firm part of the working base of geologists and seismologists."* However, several decades were to pass before Gilbert's ideas gained general acceptance.

Gilbert's earthquake warning was remarkable for its recognition that earthquakes in the Basin and Range province are unevenly distributed in time and space. He concluded that once an earthquake occurs at a particular location on a fault, it is unlikely that another will take place there until sufficient time has elapsed for the necessary strain to reaccumulate. He interpreted the absence of young fault scarps along some portions of active fault zones as evidence of long quiescence and strain accumulation, marking the subdued section of the fault as a prime candidate for a future earthquake. It was for that reason that Gilbert issued his warning to Salt Lake City. He had identified young scarps extending northward from Warm Springs at the north edge of Salt Lake City and southward from Emigration Canyon, but found scarps to be *"conspicuously absent"* (Gilbert, 1884, p. 52) along the mountain front adjacent to the city between those two points. He concluded that, *"the rational explanation of their absence is that a very long time has elapsed since their last renewal. In this period the earth strain has been slowly increasing, and some day it will overcome the friction, lift the mountains a few feet, and re-enact on a more fearful scale the catastrophe of Owens Valley"* (Gilbert, 1884, p.

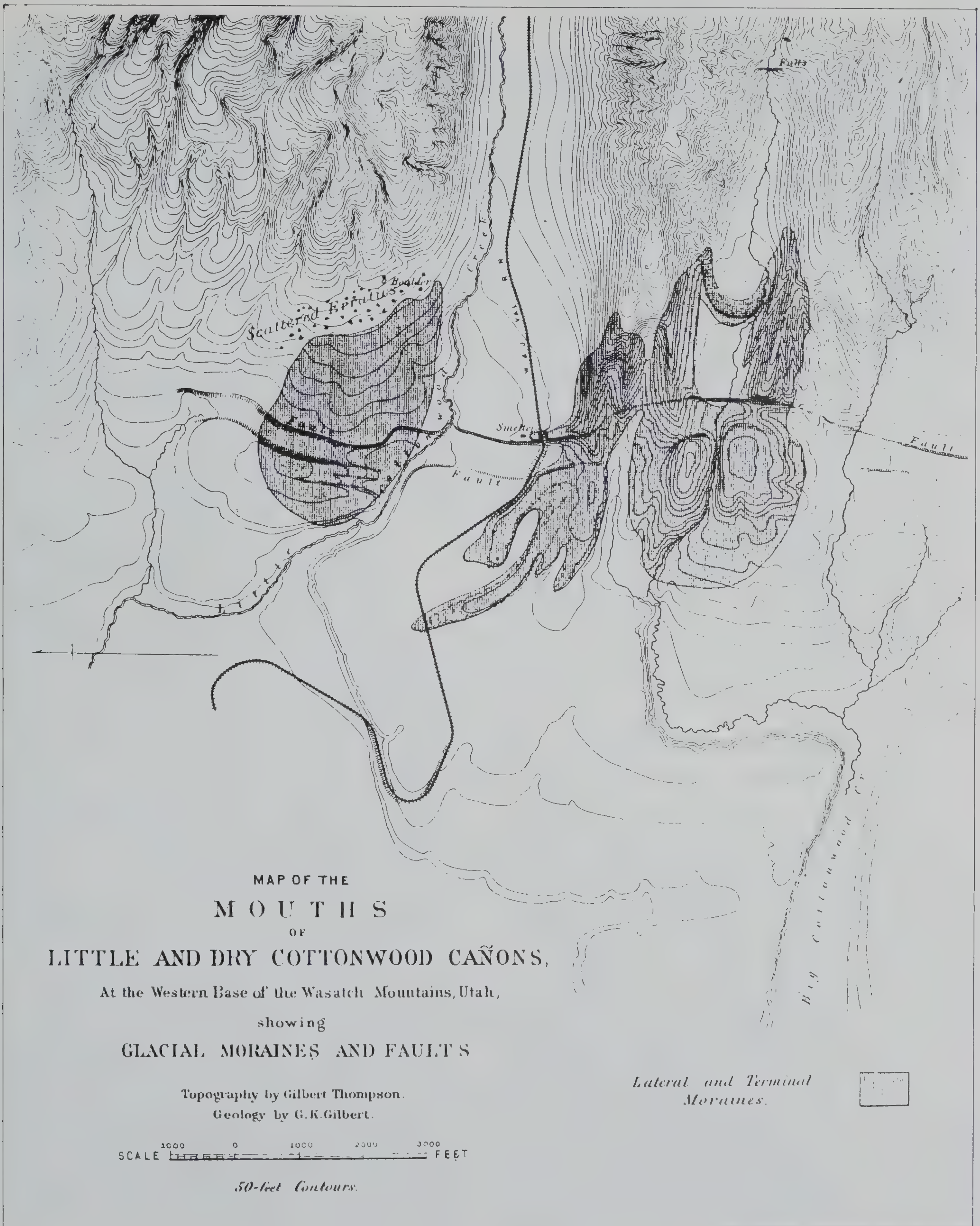


Figure 1. Gilbert's (1890), plate XLII, mapping of moraines and fault scarps at Little Cottonwood Canyon, Wasatch fault zone.

52). Gilbert considered the great 1872 Owens Valley, California earthquake (M 7.8) to be the result of the same type of forces acting on the Wasatch fault zone and, therefore, to be a model for the earthquake that would someday affect Salt Lake City.

Gilbert was perceptive about human nature and also one of the first thinkers in the field of relative risk assessment. He predicted that following the next large earthquake, *"Salt Lake City will have been shaken down, and its surviving citizens will have sorrowfully rebuilt of wood,"* a material he considered more resistant to earthquake forces based on observation of the damage to buildings in Lone Pine, California resulting from the Owens Valley earthquake (Gilbert, 1884, p. 52). Asking what the citizens of Salt Lake City were going to do about his warning, he answered, *"probably nothing."* He considered it unlikely that the city's inhabitants would *"abandon brick and stone and adobe, and build all new houses of wood."* He further concluded that even if they did rebuild the city with wood, it would only increase the danger of fire which, *"in the long run destroys more property than earthquakes"* (Gilbert, 1884, p. 53). Time has proven Gilbert's forecast of public response to his warning correct. The many unreinforced brick and stone structures (including many schools and hospitals) built in the Salt Lake City area until relatively recently are evidence that little was done through land-use planning and building codes to mitigate earthquake hazards. On the other hand, Salt Lake City never experienced a major destructive fire similar to those which occurred in many American cities before the turn of the century.

GILBERT'S EARTHQUAKE HAZARD EVALUATION OF THE WASATCH FAULT ZONE

Gilbert (1884, 1890) showed an extraordinary understanding of the geologic processes and principles critical to earthquake hazard evaluation. Geologists and seismologists studying the Wasatch fault zone today are, for the most part, either expanding on his work, pursuing ideas he germinated, or trying to answer questions he raised. Recurrence intervals, elapsed time since the most recent surface-faulting event, fault segmentation, seismic gaps, ground deformation, fault geometry, and characteristic earthquake models are all current research topics whose origins can be found in one form or another in Gilbert's work. Even his instinct for identifying the best locations to study the fault zone has proven reliable. Swan and others (1981) excavated trenches for one of the first detailed paleoseismic investigations on the Wasatch fault zone across scarps first identified and described by Gilbert (Hunt, 1982) at the mouth of Little Cottonwood Canyon. More recently, Lund and Schwartz (1987) excavated trenches at Dry Creek Canyon about 2 km south of Little Cottonwood Canyon (figure 2) on scarps examined by Gilbert in 1877 and 1880 (Hunt, 1982). The purpose of trenching is to obtain information on the size and timing of past earthquakes. Information that Gilbert, in his warning to Salt Lake City, recognized as necessary before effective earthquake hazard mitigation could take place.

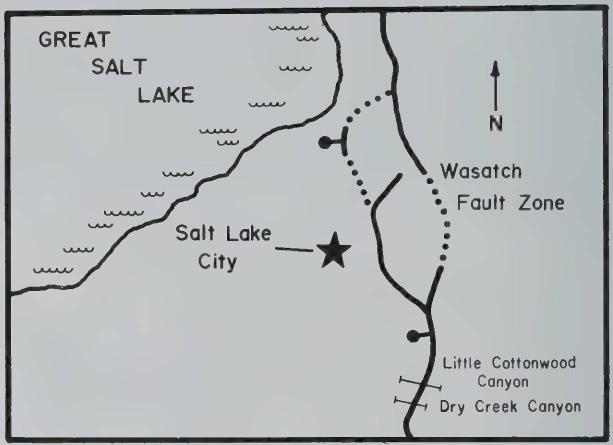


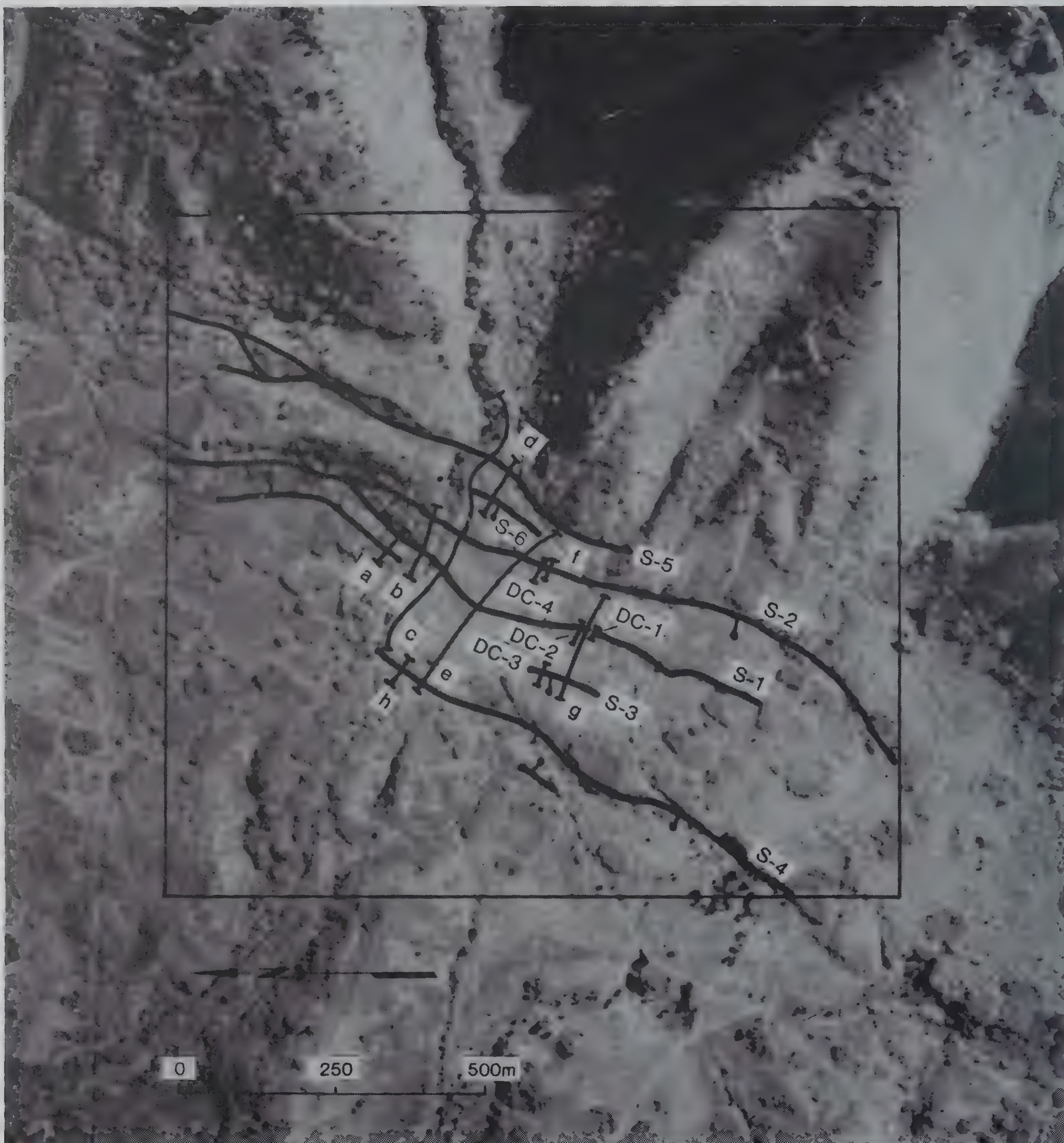
Figure 2. *Map showing location of Little Cottonwood Canyon and Dry Creek Canyon trench sites.*

RESULTS OF RECENT PALEOSEISMIC INVESTIGATIONS

The Wasatch fault zone crosses Little Cottonwood Creek (figure 3) as a major graben in Lake Bonneville lacustrine sediments and alluvial deposits. The zone of most recent faulting is conspicuous where it crosses lateral and terminal moraines at the mouths of Bells and Little Cottonwood Canyons. Immediately north of Little Cottonwood Canyon, the fault zone is defined by a steep, curvilinear, west-facing scarp and a zone of antithetic faulting 200 m (meters) wide. The heights of the antithetic scarps vary from less than 10 m to about 20 m. The main scarp is 20 to 45 m high and splays to the north into three west-facing scarps having heights of 4.5, 2.0, and 3.5 m (Hanson and Schwartz, 1982). Trenches were excavated into the westernmost of the three main fault scarps, across the graben, and into the main antithetic fault (figure 3). The trenches exposed Bonneville lacustrine sediments, post-Bonneville alluvial-fan and graben-fill deposits, Bells Canyon till, and scarp-derived colluvium. Details of the investigation are presented in Swan and others (1981) and Schwartz and Coppersmith (1984).

In summary, the trenches showed evidence for two surface-faulting earthquakes during the past 8000-9000 years. The older event occurred shortly before 8000-9000 years ago; timing of the most recent event could not be constrained. A maximum average recurrence interval of 4000-4600 years between surface-faulting events was obtained based on information from the trenches. However, estimates of earthquake recurrence at Little Cottonwood Canyon are complicated by multiple fault traces and a wide, complex zone of deformation. No subsurface data are available for the other two splays of the main fault at the trench site. Both Swan and others (1981) and Schwartz

Figure 3. *Low-sun-angle photograph showing the complexity and width of the Wasatch fault zone at the mouths of Little Cottonwood and Bells Canyons (from Swan and others, 1981).*



EXPLANATION

(trench symbol)	DC-1	Trench
(profile symbol)	a	Profile
(scarp symbol)	S-3	Scarp; bar and ball on downthrown side.

Figure 4. *Location of fault scarps, exploration trenches, and topographic profiles at the Dry Creek Canyon site.*

and Coppersmith (1984) are uncertain to what extent the parallel scarps represent additional events that could decrease the interval between surface-faulting earthquakes. An alternative recurrence interval of 2400-3000 years was calculated using a net tectonic displacement of 14.5 m measured across the Bells Canyon moraine (profile A-A', figure 3), an age for the moraine of 19,000 ± 2000 years (Madsen and Currey, 1979), and a displacement per event of 2 m determined from the depth to Bonneville lacustrine deposits displaced in the graben. Using the same value of net tectonic displacement, a slip rate of 0.76 (+0.6; −0.2) millimeters per year was calculated for the Wasatch fault zone at Little Cottonwood Canyon for the past 19,000 ± 2000 years (Schwartz and Lund, 1988). That slip rate is similar to late Pleistocene-Holocene rates determined elsewhere along the Wasatch fault zone.

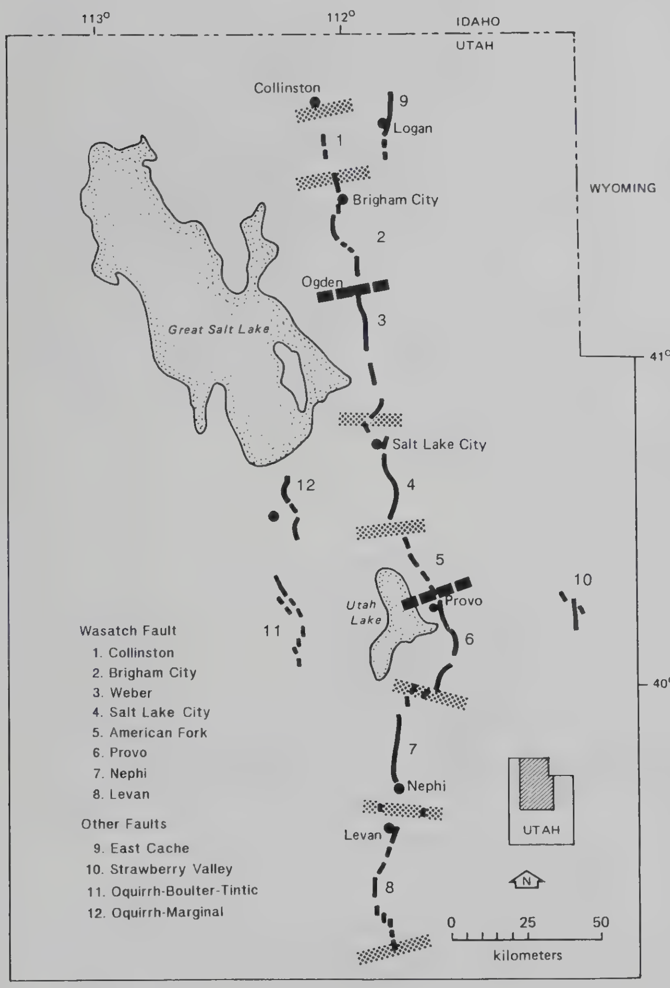


Figure 5. *Segmentation model for the Wasatch fault zone, Utah. Stippled bands define segment boundaries identified by Schwartz and Coppersmith (1984); dashed bands are additional boundaries interpreted by Machette and others (1987).*

The investigation at Dry Creek Canyon (Lund and Schwartz, 1987; Schwartz and others, 1988) demonstrated the occurrence of two middle to late Holocene surface-faulting earthquakes. Mean-residence-time radiocarbon dates of soil A horizons buried by scarp-derived colluvium show that the older event occurred shortly after 5545-5975 yr B.P. (years before the present). The timing of the most recent event is less well defined, occurring after 1130-1890 yr B.P. The Wasatch fault zone at Dry Creek Canyon consists of five parallel to *en echelon* scarps in a zone up to 300 m wide (figure 4). Displacement occurred on each scarp during the past two surface-faulting earthquakes. Topographic profiling of a debris-flow levee displaced only by the most recent event and alluvial-fan deposits displaced by both events, combined with measurements of displaced marker horizons in the trenches, indicate a net tectonic slip of 4.5-5.0 m per event for the past two surface-faulting earthquakes (Schwartz and Lund, 1988). This is the largest displacement value measured for a single event along the Wasatch fault zone.

Given the short distance (2 km) between the two trench sites, it is reasonable that the earthquakes at Dry Creek Canyon also occurred at Little Cottonwood Canyon. The inability to clearly recognize two post-middle Holocene events at Little Cottonwood Canyon is additional evidence of the uncertainty regarding the activity of individual fault scarps at that location during individual surface-faulting earthquakes. However, the similarity in style of faulting at Dry Creek and Little Cottonwood Canyons and their proximity to one another strongly suggest that the parallel scarps at Little Cottonwood Canyon slipped simultaneously during past surface-faulting earthquakes (Schwartz and Lund, 1988). The resulting larger slip per event would be more consistent with the broad fault zone and high scarps found at Little Cottonwood Canyon than the previous estimate of 2 m per event.

Combining observations from Little Cottonwood and Dry Creek Canyons indicates that at least three large-magnitude, surface-faulting earthquakes have occurred on the Wasatch fault zone near Salt Lake City in the past 8000-9000 years. One event occurred shortly before 8000-9000 years ago, one shortly after 5500-6000 years ago, and the most recent event shortly after 1100 to 1800 years ago. Considering the uncertainties in the timing of the events, an average recurrence interval of 4000 ± 1000 years appears appropriate for the Wasatch fault zone near Salt Lake City (Schwartz and Lund, 1988). However, the actual intervals separating the events may range from 2000 to 4900 years. The difference between the actual and average recurrence intervals is in part due to uncertainties in dating, but it also reflects the temporal variations that occur between earthquakes at a given location on the fault. Such variations demonstrate the need to establish the earthquake history of the Wasatch fault zone over the longest time period possible and to show that "average" recurrence intervals must be used with caution when evaluating earthquake hazards.

STATUS OF EARTHQUAKE HAZARD EVALUATION ON THE WASATCH FAULT ZONE

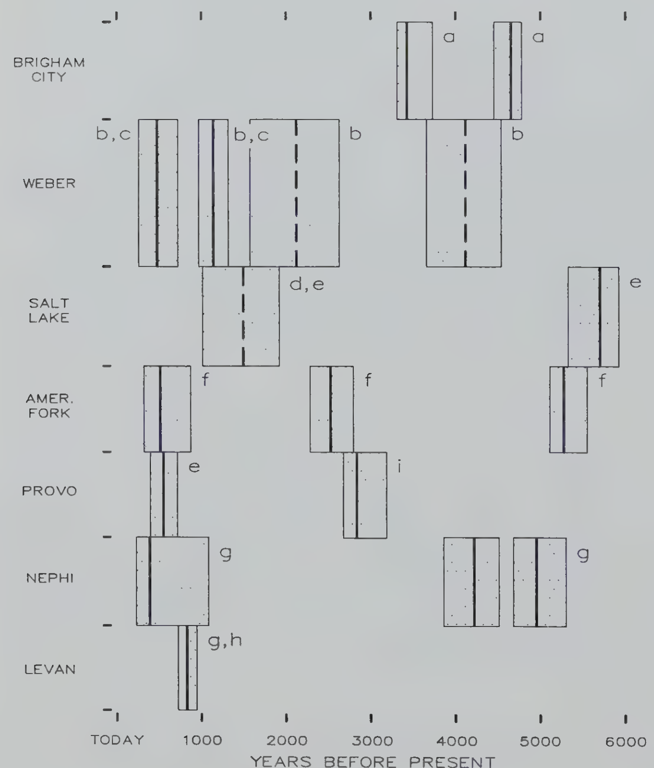
Although current earthquake hazard research on the Wasatch fault zone can trace its origins to Gilbert's pioneering efforts, systematic study of the earthquake history of the fault zone did not begin until 1977, when the first detailed paleoseismic investigation was conducted near Kaysville (Swan and others, 1980). Since then, 20 other sites have been investigated along the fault zone (Machette and others, 1987), many as part of a joint Utah Geological and Mineral Survey/U.S. Geological Survey program to investigate earthquake hazards along the Wasatch Front (Atwood and Mabey, 1987).

A reasonably accurate picture of the earthquake history of the Wasatch fault zone for the past 5000-6000 years now exists, and it is recognized that the Wasatch fault zone consists of several segments (figure 5), each essentially seismically independent of the others (Schwartz and Coppersmith, 1984; Machette and others, 1987).

Since the middle Holocene, earthquakes on the Wasatch fault zone appear to occur in clusters, short intervals of time (hundreds rather than thousands of years) during which all or most of the active fault segments experience a surface-faulting earthquake (Machette and others, 1988; Schwartz and others, 1988; figure 6). Longer periods of relative quiescence appear to follow these "bursts" of intense earthquake activity, although there is some variability, such as that which occurs along the Weber segment (figure 6). During the most recent cluster, beginning about 1200 years ago, all the fault segments recognized as active during the Holocene (with one and possibly two exceptions) have experienced a surface-faulting earthquake (figure 6). The two exceptions are the Brigham City segment where a surface-faulting earthquake has not occurred for more than 3000 years, and the Salt Lake City segment where 1100-1800 years have gone by since the last large earthquake. Studies at American Fork Canyon (Machette and Lund, 1987), Kaysville (Swan and others, 1981), and East Ogden (Nelson and others, 1987) show that more time has elapsed on the Salt Lake City segment (figure 6) since the last surface-faulting event than on adjacent segments. Although we are still far from being able to make a prediction of the time and place of the next surface-faulting earthquake on the Wasatch fault zone, it is possible to indicate a relative hazard for individual fault segments based on the timing of their most recent surface-faulting earthquake. The principle employed is the same as that stated by Gilbert in 1884: fault segments that have experienced recent surface-faulting are the least likely to generate the next earthquake. Using that criterion, the segments with the greatest elapsed time since the last surface-faulting earthquake are the most likely to experience the next event. Therefore, the Brigham City and Salt Lake City segments are the most probable candidates for the next large-magnitude, surface-faulting earthquake on the Wasatch fault zone. In the case of Salt Lake City, this confirms what Gilbert predicted 105 years ago.

Readers interested in Wasatch Front neotectonics should find the field trip guidebook (no. 12) for the annual Geological Society of America meeting of great interest (see review in this issue of "In the Footsteps of G.K. Gilbert ...").

WASATCH FAULT ZONE RECURRENCE



Sources of data:
a. S. Personius in Machette et al., 1988.
b. A. Nelson in Machette et al., in prep.
c. Swan et al. (1980)
d. Lund and Schwartz (1987)
e. Schwartz et al. (1988)
f. Machette et al. (1987)
g. Schwartz and Coppersmith (1984)
h. M. Jackson, M.A. Thesis, U. Colorado, 1988.
i. W. Lund (written communication)

Figure 6. *Space-time plot of large-magnitude earthquakes along the Wasatch fault zone during the past 6000 years. Heavy solid line indicates best estimate of timing; heavy dashed line is approximation. Stippled boxes reflect uncertainties to timing based on age dates and stratigraphic relationships (Compiled by David Schwartz, U.S. Geological Survey).*

STATE OF UTAH
NATURAL RESOURCES
Utah Geological & Mineral Survey

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Genevieve Atwood, State Geologist

606 Black Hawk Way•Salt Lake City, UT 84108-1280•801-581-6831

Dear Fellow Geologists:

We have many inquiries regarding Utah geology in areas where published geologic coverage is unavailable or inadequate, and where unpublished field mapping or other geologic studies have been done, are being done, or are planned. Therefore, the Utah Geological and Mineral Survey is soliciting your cooperation for our computerized listing of those areas in Utah being studied by geoscientists in your university or agency during the upcoming field season (Summer, 1989) and next season (Summer, 1990).

Please circulate this form among your staff for the required information, and return the information as soon as possible. On the map on the reverse side of this page, indicate the quadrangles covered (or to be covered). More copies are available on request.

If you know of any other universities or organizations who are doing geological work in Utah, please send us their names.

To assist those doing geological work in Utah, the Utah Geological and Mineral Survey has compiled a bibliography of the Geology of Utah on computer. Special searches can be made by quadrangle, formation, commodity, type of study, etc. Please write for more information.

Many thanks for filling out this form. A copy can be obtained by request at no charge.

Genevieve Atwood

Genevieve Atwood, *Director*
Utah Geological and Mineral Survey

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Investigator: ______

Organization/School: ______

Address: ______
City State Zip

Title/Subject: ______

Scope and class (i.e., detailed, reconnaissance, photo interpretation - with or without field checking, etc.): ______

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Date of proposed completion: ______

Probable location of information (i.e., University thesis, open-file - where; release date and provisions, where; state or technical agency - where; publication - where; company confidential.): ______

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May we have a copy of the completed report and map for our library: ☐ Yes ☐ No

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Scale of map: ______

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Commodities: ______

______

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☐ Hydrology ☐ Mineralogy ☐ Hard rock geology

☐ Paleontology
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______

☐ Quaternary Soils ☐ Petrology ☐ Volcanology

☐ Sedimentology ☐ Structural geology

☐ Stratigraphy
Formation, age: ______

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☐ Other (please specify): ______

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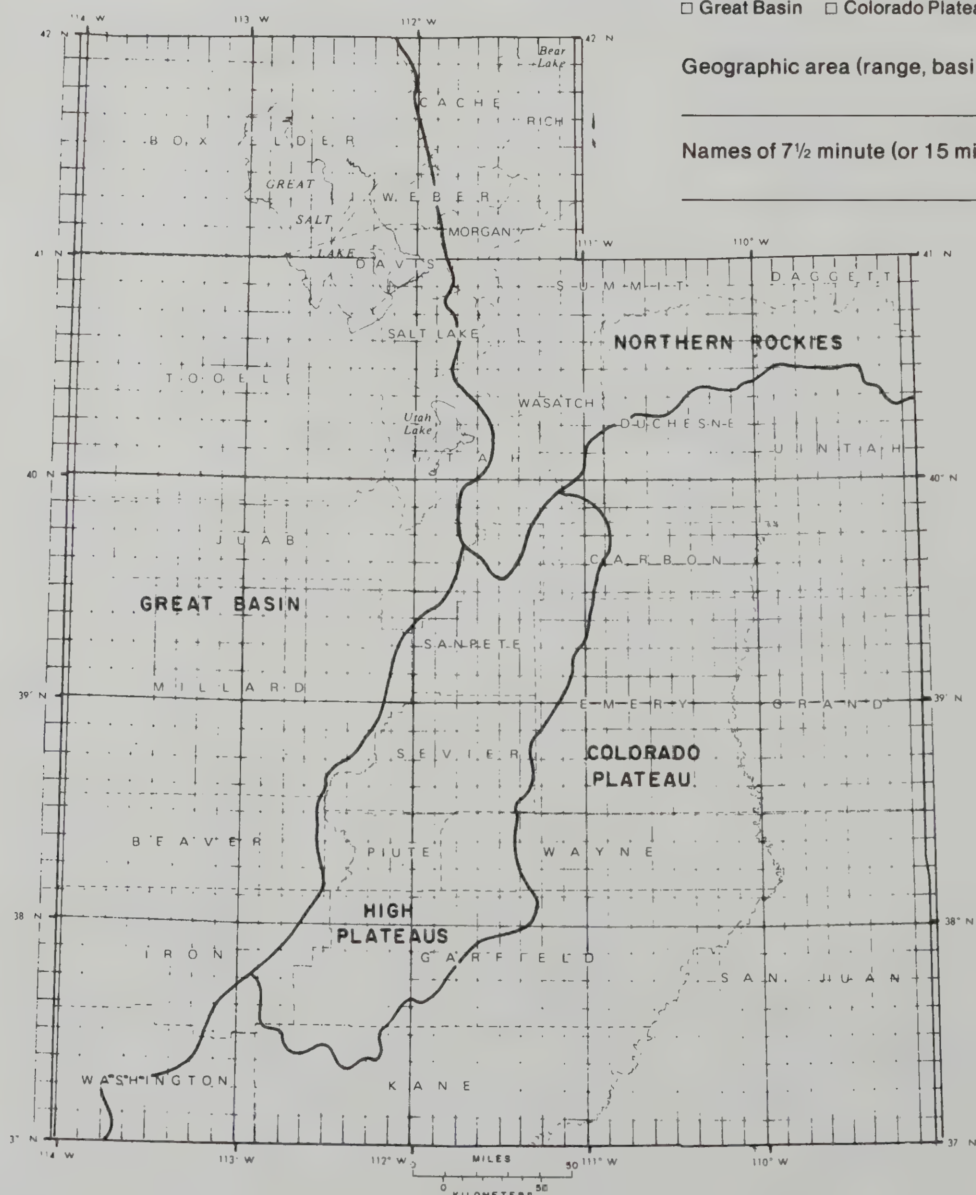

Principal physiographic provinces of Utah covered by this study:

☐ Great Basin ☐ Colorado Plateau ☐ Northern Rockies ☐ High Plateaus

Geographic area (range, basin, etc.): ____________________

____

Names of 7½ minute (or 15 minute) quadrangles: ______________

____

Which Counties are covered by this study?
(please circle)

All Counties	Morgan
Beaver	Piute
Box Elder	Rich
Cache	Salt Lake
Carbon	San Juan
Davis	Sanpete
Daggett	Sevier
Duchesne	Summit
Emery	Tooele
Garfield	Uintah
Grand	Utah
Iron	Wasatch
Juab	Washington
Kane	Wayne
Millard	Weber

If possible, please fill in location of study area on this map of Utah. Each small square equals one 7½ minute quad.

Acknowledgements

I thank Gary Christenson, Kimm Harty, and Suzanne Hecker of the Utah Geological and Mineral Survey, and David Schwartz of the U.S. Geological Survey for their timely review of this article. Their comments and suggestions were of great assistance and improved both the accuracy and readability of the final product.

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Books & Papers

Hydrology of Alkalai Creek and Castle Valley Ridge coal lease tracts, central Utah, and potential effects of coal mining, by R.L. Seiler, and R.L. Baskin, 53 p., 2 pl., 1988, U.S. Geological Survey WRI-87-4186.

Utah ground-water quality, by K.M. Waddell, and M.H. Maxwell, 10 p., 1987, U.S. Geological Survey OF 87-0757.

Mineral resources of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah, by R.E. Van Loenen, E.G. Sable, H.R. Blank, Jr., H.N. Barton, K.L. Cook, and J.E. Zelten, 18 p., 1 pl., 1988, U.S. Geological Survey B 1746-B.

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Mineral resources of the Mt. Hillers Wilderness Study Area, Garfield County, Utah, by R.F. Dubiel and others, 14 p., 1 pl., 1988, U.S. Geological Survey B 1751-C.

Interim geologic maps and explanation pamphlet for parts of the Stockton and Lowe Peak 7½-minute quadrangles, Utah, by E.W. Tooker, and R.J. Roberts, 20 p., 2 pl., 1988, U.S. Geological Survey OF 88-0280.

Maps of fault scarps formed on unconsolidated sediments, Tooele 1° x 2° quadrangle, northwestern Utah, by T.P. Barnhard, and R.L. Dodge, 1 pl., 1988, U.S. Geological Survey MF 1990.

Geologic map showing a late Cenozoic basaltic intrusive complex, Emery, Sevier, and Wayne Counties, Utah, by A.E. Gartner, and P.T. Delaney, 1 pl., 1988, U.S. Geological Survey MF 2052.

Diagenesis and burial history of nonmarine Upper Cretaceous rocks in the central Uinta Basin, Utah, by J.K. Pitman, K.J. Franczyk, and D.E. Anders, 24 p., 1988, U.S. Geological Survey B 1787-D.

Land use and land cover and associated maps for Salina, Utah, U.S. Geological Survey OF 85-0316.

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Geology of Antelope Island, Davis County, Utah, by Hellmut H. Doelling and others. Utah Geological and Mineral Survey OF 144, 1988, 99 p., 2 pl., scale 1:24,000.

Antelope Island is a small fault block mountain range in the Basin and Range physiographic province of Utah. It is the largest and most prominent of several islands in the Great Salt Lake and is located in the lake's southeastern corner. The island contains Precambrian high-grade metamorphic rocks, Late Precambrian and Cambrian metasedimentary rocks, Tertiary conglomerates, mudstones, dolomites, tufaceous sandstones, and volcanic air fall tuffs, and Quaternary Lake Bonneville and Great Salt Lake sediments.

The report is divided into five different sections: rock units; structural geology including metamorphic structures, faults, shear zones, and folding and tilting; geologic history; economic geology with mineral resources grouped into metallic deposits (copper and iron) and non-metallic or construction materials; and geologic hazards such as landslides, debris flows, rock falls, lake flooding and erosion, and earthquake ground shaking.

Quaternary Geology — Tule Valley, West-Central Utah, by Dorothy Sack. Utah Geological and Mineral Survey OF 143, 1988, 60 p., 1 pl., scale 1:100,000.

Tule Valley is located about 130 miles southwest of Salt Lake City and 45 miles west of Delta, Utah in Juab and Millard Counties and occupies a structural basin of interior drainage in the Basin and Range physiographic province. It is bordered by the House Range on the east, the Confusion Range on the west, and by portions of the Fish Springs Range, Middle Range, and Honeycomb Hills on the north. Quaternary deposits include alluvial, eolian, lacustrine, mass movement, playa, spring, and bedrock. Also discussed is the valley's late Quaternary history, economic geology, springs, and geologic hazards.

Geologic History of Utah, by Lehi F. Hintze. Brigham Young University Geology Studies Special Publication 7, 1988, 102 p. Lehi F. Hintze, professor emeritus of geology at Brigham Young University, has completed a revised edition of his popular 1973 book on the geology of Utah. This new publication, primarily for beginning students of geology, employs new information about local and regional geology of Utah. Professor Hintze begins his book with a general overview of Utah's topography and geology and discusses the imprint that each geologic period left on our state. This publication is complemented by numerous photographs and schematic drawings as well as an extensive bibliography and 102 stratigraphic sections from strategic locations throughout the state.

Geologic Consequences of the 1983 Wet Year in Utah, by Bruce N. Kaliser and James E. Slosson, PhD. Utah Geologic and Mineral Survey Miscellaneous Publication 88-3, 1988, 109 p. The hydrologic and climatologic settings in Utah during the 1982, 1983 and 1984 wet cycle produced saturated and supersaturated soils that ultimately resulted in extensive debris flows. This paper briefly examines meteorological conditions and their impact on geologic events during Utah's "wet years." The area studied includes 24 of Utah's 29 counties (eliminating five counties in the southeastern quarter of the state). Types of slope movement monitored or observed during the time frame includes translational and rotational debris slides. The study analyzes specific debris flows that occurred during this historic period.

In the Footsteps of G.K. Gilbert—Lake Bonneville and Neotectonics of the Eastern Basin and Range Province, edited by Michael N. Machette. Utah Geological and Mineral Survey Miscellaneous Publication 88-1, 1988, edited as a guidebook for the October 1988 GSA meeting, 120 p.

This publication contains road logs for three one-day field trips. The field trip focuses on both the Wasatch fault zone and geomorphic features of Lake Bonneville. Papers include discussions of G.K. Gilbert's classic stratigraphic and geomorphic localities in this portion of Utah. Data from new sites is introduced along with a close examination of Gilbert's interpretations in light of modern theories and a regional tectonic framework. Gilbert's three primary interests that are examined include: geomorphology of Lake Bonneville deposits, the stratigraphy of the lacustrine cycles of Lake Bonneville, and neotectonics of the eastern Basin and Range province.

Salt Deformation in the Paradox Region, by H.H. Doelling, C.G. Oviatt, and P.W. Huntoon. Utah Geological and Mineral Survey Bulletin 122, 1988, 93 p.

UGMS Bulletin 122 is a compilation of three research projects conducted on thick salt sequences in the Paradox Basin area of southeastern Utah. The first article, "The geology of Salt Valley anticline and Arches National Park, Grand County, Utah," by Hellmut H. Doelling studies one of the salt anticlinal structures in the Paradox Basin. The article discusses local stratigraphy, structure and examples of how salt has helped shape the landscape. This study is a companion to previously published UGMS Map 74, "The geologic map of Arches National Park and vicinity, Grand County, Utah."

The second article in this bulletin is "Evidence for Quaternary salt deformation in the Salt Valley anticline, southeastern Utah." The author, Charles G. Oviatt, discusses local stratigraphic and geomorphic evidence of folding, faulting and other forms of deformation. Volcanic ash beds lend dates to deformation, thus giving credence to theories that active dissolution and diapirism still exist in the area.

Peter W. Huntoon's article "Late Cenozoic gravity tectonic deformation related to the Paradox salts in the Canyonlands area of Utah" relates deformation of rocks overlying the salt to three active mechanisms. Huntoon points out that salt dissolution, salt flowage and gliding of the rocks above the salt are events that occurred due to the erosion of the Colorado River and its tributaries. The article presents evidence that these processes continue to be active and are destabilizing the salt.

Devonian, Carboniferous, and Permian stratigraphy of the Burbank Hills in western Millard County, Utah by Lehi F. Hintze. Published in the New Mexico Bureau of Mines and Mineral Resources memoir 44, 1988.

Doctor Hintze's paper is a diagnostic summary of the present concept of stratigraphy for this area in west-central Utah in order to provide a basis for future work. The excellent discussion also includes a thorough reference list useful to future mappers, paleontologists, and stratigraphers.

Old Utah Trails by William B. Smart. This is the fifth of the Utah Geographic Series (Utah Canyon Country, Utah Ski Country, Utah Wildlands, Utah's Wasatch Front), good looking, well done, and informative mini-coffee-table publications. This 1988 book details 8 of the famous expeditions/tracks through Utah with a good array of text, maps, and photographs. Personal rather than scholarly, it is not only readable but accurate in combining current advice on travel with primary source excerpts to depict the trials and trails through Utah's geologic milieu.

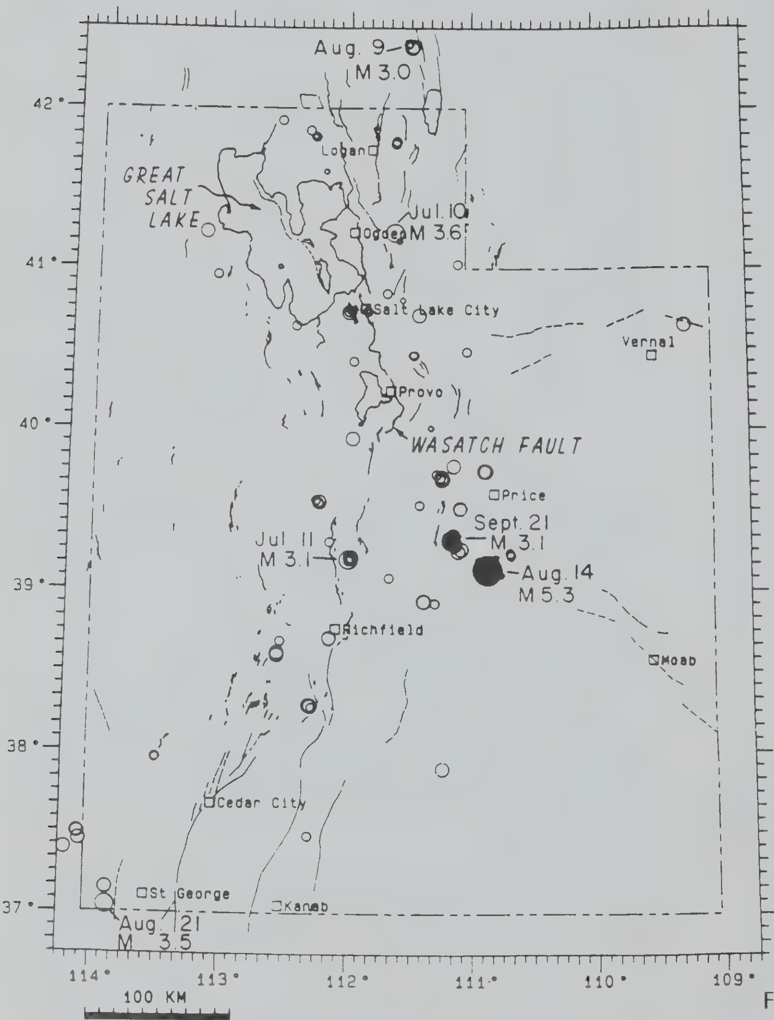
Stone House Lands: The San Rafael Reef by Joseph M. Baumon, Jr. Like Old Utah Trails, this is personalized natural history of a particular part of Utah. The chapter titled "The Environment, Then and Now" is a good layman summation of geologic and environmental history. A University of Utah Press publication.

UTAH EARTHQUAKE ACTIVITY

by Susan J. Nava

UNIVERSITY OF UTAH SEISMOGRAPH STATIONS, DEPARTMENT OF GEOLOGY AND GEOPHYSICS

Utah Earthquakes July through September, 1988



During the three-month period July 1 through September 30, 1988, the University of Utah Seismograph Stations located 260 earthquakes within the Utah region (see accompanying epicenter map). Of these earthquakes, 86 had a local magnitude (M_L) or coda magnitude (M_C) of 2.0 or greater, nine had a magnitude of 3.0 or greater, and eight were reported felt.

The largest earthquake during the report period was a shock of M_L 5.3 on August 14 at 2:03 PM MDT on the northwest edge of the San Rafael Swell in central Emery County, 20 km southeast of Castle Dale, Utah. This was the largest earthquake to occur in the Utah region since the 1975 M_L 6.0 Pocatello Valley earthquake. The Emery County earthquake was felt strongly throughout central Utah (Modified Mercalli Intensity V to VI), where it caused some minor damage, and was reported felt as far away as Golden, Colorado and Albuquerque, New Mexico. Six foreshocks of M_L1.8 to 3.8 occurred during the 65 minutes prior to the main shock. The two largest foreshocks, of M_L2.9 at 12:58 PM MDT and of M_L3.8 at 1:07 PM MDT, and the largest aftershock of M_L4.4 on August 18 at 6:44 AM MDT, were felt in nearby small towns. The second largest aftershock, of M_L3.0, occurred on August 15 at 8:50 AM MDT. During the report period, 147 earthquakes associated with the San Rafael Swell sequence have been located. The aftershocks form an epicentral zone, 3 x 4 km adjacent to the main shock epicenter and elongated slightly in a north-northeast direction and a hypo-central zone extending from 8 to 15 km in depth and dipping 60°-70° east-southeast, with a length along strike of 4 km and a downdip extent of 8 km. (A preliminary seismological summary of "The Magnitude 5.3 San Rafael Swell, Utah, earthquake of 14 August 1988" by S.J. Nava, J.C. Pechmann, and W.J. Arabasz appeared in the last issue of Survey Notes.

Five other earthquakes of magnitude 3.0 and greater occurred in the Utah region during the report period: M_L 3.6 on July 10 at 2:45 PM MDT, located 30 km east of Ogden, Utah; M_L 3.1 on July 11 at 5:46 AM MDT, felt at Fayette, Utah; M_C 3.0 on August 9 at 5:07 PM MDT, located 25 km southeast of Soda Springs, Idaho; M_L 3.5 on August 21 at 5:21 PM MDT, located 30 km southwest of St. George, Utah; and M_C 3.1 on September 21 at 11:58 AM MDT, located 20 km west of Huntington, Utah. Additional earthquakes reported felt in Utah during the report period included shocks of: M_L 1.6 on August 23 at 11:13 PM MDT, felt in Salt Lake City; M_L 2.7 on September 8 at 3:42 PM MDT, felt at Goshen; and M_L 2.4 September 23 at 7:40 PM MDT, felt in West Valley City and Magna.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations.

Geo-Calendar

Meeting information is as accurate as we can make it. Listings may be sent to Survey Notes Editor, *but we're picky.*

A UTAH CHAPTER OF THE SOCIETY FOR INDUSTRIAL ARCHAEOLOGY was formed October 14 in Salt Lake City. Their first newsletter divulges diverse details concerning purpose, style and goals of the SIA. Contact Gary Daynes for information on the newsletter and to submit articles: 342 South 1200 East, #2, Salt Lake City, Utah 84102.

Feb. 8-10 MINING-INVESTMENT IN THE FUTURE, conference and exhibit. Denver, CO. Contact Colorado Mining Association, 1500 Grant Street, No. 330., Denver, CO 80203. (303) 894-0536.

Feb. 13-14 GEOPHYSICS OF THE ROCKY MOUNTAINS, MEETING in Golden, CO. Contact Front Range AGU Service Center, Box 18-P, Denver, CO 80218. (303) 831-6338.

Feb. 27-Mar. 2 SOCIETY OF MINING ENGINEERS 1989 ANNUAL MEETING AND TMS ANNUAL MEETING will be in Las Vegas, Nevada at the Las Vegas Convention Center. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162, (303) 973-9550.

Mar. 6-8 ROCKY MOUNTAIN SECTION, SOCIETY OF PETROLEUM ENGINEERS MEETING, Denver, CO. Contact Front Range AGU Service Center, Box 18-P, Denver, CO. 80218. (303) 831-6338.

Mar. 12-14 GSA SOUTH-CENTRAL SECTION MEETING in Arlington. Contact William L. Balsam, Dept. of Geology, Box 19049, Univ. of Texas, Arlington, TX 76019, (817) 273-2987.

Mar. 13-16 APPLICATION OF GEOPHYSICS TO ENGINEERING & ENVIRONMENTAL PROBLEMS, MEETING, Golden, CO. Contact Ron Bell, BellWest Geoservices, Box 10845, Edgemont Branch, Golden, CO 80401. (303) 237-5697.

Mar. 19-21 SOUTHWEST SECTION, AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS MEETING, San Angelo, TX. Contact AAPG, Box 979, 1444 S. Boulder, Tulsa, OK 74101. (918) 584-2555.

Mar. 20-23 ENGINEERING GEOLOGY AND GEOTECHNICAL ENGINEERING MEETING, Reno, NV. Contact Eng. Symp., Division of Continuing Education, Univ. of NV, Reno, NV 89557-0024 (702) 784-4046.

Mar. 23-25 GSA NORTHEASTERN SECTION MEETING in New Brunswick. Contact Richard K. Olsson, Dept. of Geological Sciences, Rutgers-The State University, New Brunswick, NJ 08903, (201) 932-2044.

Apr. 6-7 GSA SOUTHEASTERN SECTION MEETING in Atlanta. Contact J.A. Whitney, Dept. of Geology, University of Georgia, Atlanta, GA 30602, (404) 542-2652.

Apr. 5-7 SOCIETY OF PETROLEUM ENGINEERS REGIONAL MEETING, Bakersfield, CA. Contact SPE, Box 833836, Richardson, TX 75083-3836. (214) 669-3377.

Apr. 20-21 GSA NORTH-CENTRAL SECTION meeting in Notre Dame. Contact Michael J. Murphy, Dept. of Earth Sciences, Univ. of Notre Dame, Notre Dame, IN 46556, (219) 239-6686.

Apr. 23-26 AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS 74TH ANNUAL CONVENTION, San Antonio, TX. Contact AAPG, Box 979, 1444 S. Boulder, Tulsa, OK 74101. (918) 584-2555.

May 3-5 WESTERN SURFACE COAL MINING MEETING, Gillette, Wyoming. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO.

May 7-10 ROCKY MOUNTAIN AND CORDILLERAN SECTIONS, GSA JOINT MEETING held in Spokane, WA. Contact Sandra Rush, GSA Communications Dept., P.O. Box 9140, 3300 Penrose Place, Boulder CO 80301; (303) 443-8489.

May 20-24 FOURTH U.S. NATIONAL CONFERENCE ON EARTHQUAKE ENGINEERING, in Palm Springs, CA. Contact Dee Czaja, 4NCEE, Civil Engineering Dept., Univ. of California, Irvine, CA 92717, (714) 856-8693.

July 9-19 28TH INTERNATIONAL GEOLOGICAL CONGRESS, Washington, D.C. For information contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001, (703) 648-6053.

July 30-Aug. 2 SOIL AND WATER CONSERVATION SOCIETY 44TH ANNUAL MEETING in Edmonton, Alberta, Canada. Contact Alfred Birch, 7515 N.E. Ankeny Road, Ankeny, IA 50021.

Aug. 13-23 FRIENDS OF THE PLEISTOCENE, ROCKY MOUNTAIN CELL, 1989 FALL FIELD TRIP. Contact Pete Birkeland, Dept. Geological Sciences, Campus Box 250, Univ. of Colorado, Boulder, CO 80309.

Sept. 10-14 EDITING INTO THE NINETIES. Joint meeting at the Westin Hotel in Ottawa, Canada of Council of Biology Editors, European Assn. of Science Editors, Assn. of Earth Science Editors, and National Research Council of Canada. Contact Ken Charbonneau, Executive secretary, National research Council of Canada, Ottawa, Canada K1A OR 6, (613) 993-9009.

Sept. 10-14 WYOMING GEOLOGICAL ASSOCIATION 40TH FIELD CONFERENCE. Contact Lynette George, 2220 Volcaro Rd., Casper WY 82604 (307) 265-0775 or Stephen Hollis, PO Box 1068, Casper WY 82602 (307) 577-7460.

Oct. 1-6 ASSOCIATION OF ENGINEERING GEOLOGISTS ANNUAL MEETING, Vail, CO. Contact Denver Section, AEG, P.O. Box 15124, Denver CO 80215.

Oct. 23-26 FOURTH INTERNATIONAL CONFERENCE ON SOIL DYNAMICS AND EARTHQUAKE ENGINEERING, in Mexico City, Mexico. Contact A.S. Cakmak, Dept. of Civil Engineering, Princeton University, Princeton, NJ 08544, (609) 452-4601.

Nov. 6-9 GSA ANNUAL MEETING in St. Louis. Contact Sandra Rush, GSA Communications Dept., 3300 Penrose Place, Box 9140, Boulder, CO 80301, (303) 447-8850.

New Publications from the UGMS

Effective January 1, 1989. The UGMS is continually striving to improve our service to geoscientsts in industry, government, and higher education, and to policy-makers and the general public. One way is to make UGMS information more available and easier to obtain. To this end, we now accept mail and telephone requests for publications without requiring prepayment. There is no further charge (postage is now paid by us) except for the Utah sales tax for Utah residents.

Report of Investigation 218 Technical reports of the Wasatch Front County Geologists June 1985-June 1988, compiled by B.D. Black and G.E. Christenson, 154 p., 1988 .... $7.50

Open-File Report 140 Geology of Calico Peak quadrangle, Kane County, Utah, by H.H. Doelling and F.D. Davis, 40 p., 1 pl., 1:24,000, 1988 .... $5.50

Open-File Report 141 Geology of Lampo Junction quadrangle, Box Elder County, Utah, by D.M. Miller, M.D. Crittenden, Jr., and T.E. Jordan, 49 p., 2 pl., 1:24,000, 1988 .... $8.00

Open-File Report 142 Geology of the Cannonville quadrangle, Kane and Garfield Counties, Utah, by R. Hereford, 25 p., 1 pl., ... $4.00

Open-File Report 143 Quaternary geology — Tule Valley, west-central Utah, by D. Sack, 60 p., 1 pl., 1988 .... $8.00

Circular 80 Annual production and distribution of coal in Utah, by A.D. Smith and F.R. Jahanbani, 8 p., 1988 .... $2.50

Bulletin 122 Salt deformation in the Paradox region, by H.H. Doelling, C.G. Oviatt, and P.W. Huntoon, 93 p., 1988 .... $9.50

Miscellaneous Publication 88-3 Geologic consequences of the 1983 wet year in Utah by B.N. Kaliser and J.E. Slossen, 109 p., 1988 .... $13.50

Open-File Report 135 Thematic mapping applied to hazards reduction, Davis County, Utah, by B.N. Kaliser, 18 p., 1988 ..... $2.00

Open-File Report 138 Geology of the Crater Island quadrangle, Box Elder Co., Utah by D.M. Miller, T.E. Jordan, and R.W. Allmendinger, *available for public inspection at the UGMS Library.*

Open-File Report 139 Geology of the Lucin 4SW quadrangle, Box Elder Co., Utah, by D.M. Miller, T.E. Jordan, and R.W. Allmendinger, *available for public inspection at the UGMS Library.*

Open-File Report 82-DF Significant drill hole data of the Wasatch Front valleys, including Cache Valley and Tooele Valley, Utah by W.F. Case and C.D. Burt, 27 p., 1 5¼" diskette $5.00

Miscellaneous Publication 80-1 In the footsteps of G.K. Gilbert — Lake Bonneville and neotectonics of the eastern Basin and Range Province, guidebook for field trip twelve, Geological Society of America annual meeting, 120 p., 1988 .... $8.50

Open-File Report 144 Geology of Antelope Island, Davis County, Utah, by H.H. Doelling and others, 99 p., 2 pl., 1988, *available for public inspection at the UGMS Library.*

Map 107 Geologic map of the Howell quadrangle, Box Elder County, Utah, by T.E. Jordan, R.W. Allmendinger, and M.D. Crittenden, Jr., 10 p., 2 pl., 1:24,000, 1988 .... $5.00

Map 109 Geologic map of the Thatcher Mountain quadrangle, Box Elder County, Utah, by T.E. Jordan, M.D. Crittenden, Jr., R.W. Allmendinger, and D.M. Miller, 10 p., 2 pl., 1:24,000, 1988 .... $5.00

Map 54-C Ground-water resources of the central Wasatch Front area, Utah, by Don Price, 5 p., 3 pl., 1:100,000, 1988 .... $6.00

The latest publications catalog is available upon request!

Call For Papers

Those wishing to present papers at the *World Gold '89—Gold Forum Technology & Practices* meeting to be held October 22-25, 1989 are invited to submit a 200-word abstract. Held at Bally's Hotel, Reno, Nevada, the meeting is sponsored by Society of Mining Engineers and The Australasian Institute of Mining and Metallurgy. Submit abstracts to:

Meetings Department—World Gold '89
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550

A call for papers has been issued for the 1990 Society of Mining Engineers Annual Meeting, February 26-March 1, Salt Lake City, Utah. The deadline for receipt of preliminary abstracts is February 1, 1989.

To receive details of the proposed session topics, contact:

Meetings Department
Society of Mining Engineers
P.O. Box 625002
Littleton, CO 80162
(303) 973-9550, Telex: 881988, Fax: 303-973-3845.

Utah Geological Association requests papers for a 1989 conference/field trip focusing on geology and hydrology of hazardous-waste, mining-waste, wastewater or brine-disposal, and waste-repository sites in Utah. Tentatively scheduled for October 6-7 in Salt Lake City, the meeting will have papers printed in The Proceedings Guidebook and given orally. Brief descriptions are due December 1 and drafts by April 1, 1989. Contact:

Joseph S. Gates
U.S. Geological Survey, WRD,
1745 W. 1700 S., Salt Lake City, UT 84104.
(801) 524-4073 or (801) 524-4244.

Geological Society of America annual meeting in St. Louis, Missouri. Abstracts are due July 19. Abstracts Coordinator GSA, 3300 Penrose Place, P.O. Box 9140, Boulder, CO 80301, (303) 447-8850.

UGMS Projects

Readers of the last issue of Survey Notes will remember Director's Corner and the lead article by Genevieve Atwood on the "Sunset legislation" and its impact on the UGMS. Every year UGMS defines goals and how to achieve them. Goals and schedules are adjusted within the framework of the legislative mandate which defines the UGMS, and within the constraints of personnel and funding. The review process generates lists of projects, and the following is a very simplified version of that listing showing much of our current effort.

Newcastle geothermal project: a cooperative study with the U.S. Department of Energy to characterize the geology and geohydrology of a hydrothermal system near this town. Includes ground-based gravity and magnetic surveys, geologic mapping of bedrock and surficial deposits, shallow temperature gradient monitoring, soil-mercury geochemical sampling, water chemistry and O/H isotopic study.

Mineral evaluation of selected wilderness study areas in Kane County. The Department of Community and Economic Development for the state of Utah has elicited the help of UGMS to become better informed with regard to mineral potential of proposed Wilderness Study Areas in this county.

Land exchange study. The Division of State Lands and Forestry has requested that UGMS assist in determining mineral resource potential of certain tracts of state land within military reservations, and national parks and monuments. These tracts will then be compared to the mineral potential of land that the state wishes to exchange with the Bureau of Land Management.

Mineral occurrence map series. UGMS is preparing a series of maps showing mineral occurrences for Utah. The Tooele 1° x 2° sheet (1:250,000 with district maps at 1:48,000) is in review. The Delta and Cedar City 1° x 2° sheets are in progress.

Quaternary deposits in Millard County. This is one of the COGEOMAP projects (see Survey Notes v. 21, no. 2-3 for an explanation of this cooperative program) for geologic mapping in western Utah; scale 1:100,000.

Earthquake hazards map of Utah. A map at 1:750,000 scale and text depicting surface fault rupture, ground shaking, liquefaction, and other hazards in the state. The map is designed for use by planners in assessing hazards at a regional scale.

Quaternary faults, folds and selected volcanic features of the Cedar City 1° x 2° quadrangle, south-western Utah. A map at 1:250,000 and text for use in evaluating the potential for large earthquakes in southwest Utah, and for documenting Quaternary structural features and tectonics. Cooperative with U.S. Geological Survey.

Brochures on the economic geology of Utah's 29 counties for non-geologists in cooperation with DCED. The first one will be Box Elder.

Great Salt Lake research: ongoing collection, study, and interpretation of brine chemistry.

West Desert pumping-resource monitoring. A multi-agency effort to monitor the salt resource and the pumping effects.

Salines of Utah. In-depth study of oil-well brines, lake brines, geothermal brines, bedded salts.

Quadrangle mapping. UGMS, USGS, other professionals, and students map the geology of 7.5-minute quadrangle under UGMS auspices for publication at 1:24,000. The Spring issue will have a detailed summary of this program.

Sewer inflow-infiltration during the wet years 1982 to 1984.

Quaternary geology of the Newcastle 7.5-minute quadrangle, Iron County, Utah. Geologic mapping deposits in conjunction with USGS at 1:24,000.

Problem soils map of Utah. Compilation map at 1:750,000 scale of expansive and collapsible soils, karst, piping and erosion areas for regional planning purposes.

Wastewater disposal study. Map soil cover and bedrock to examine waste disposal problems in Duchesne County.

Geologic mapping of the Keg Pass 7.5-minute quadrangle. Mapping at 1:24,000 plus 1:48,000 mapping of the surrounding area as part of the U.S. Geological Survey Delta CUSMAP (see Survey Notes, v. 20, no.4).

Coal sample bank. Cooperative project with Fuels Department of University of Utah to characterize the producing coal seams of Utah. Samples from 24 active coal mines representing 15 seams are examined for macerals and ranked by reflectance.

Landslide inventory map of Utah. Compilation of data (at 1:100,000) to create a computer database and produce a regional map at 500,000.

National Coal Resource Data System. Cooperative agreement with USGS to compile and interpret coal data of Utah.

UGMS Projects, continued

Wasatch Fault trenching studies. Trenching and detailed analysis of faults along the valley margin to determine age, recurrence time, etc.

Regional assessment of geologic conditions for landfills. County-wide study of Sevier Co. at 1:100,000 to define areas geologically suitable for landfills.

High-calcium limestone resources of Utah. UGMS is preparing a sampling program of limestone units capable of yielding material for coal mine dusting, flux in steel and copper smelting, flue gas desulfurization, cement, and lime manufacturing.

Methane research. An examination of Methane resources of Utah; joint study with University of Utah; funded by DOE.

Henry Mountains and Alton Coal Field studies. Cross sections and isopachs of known coal resources.

Quaternary fault map of Utah. Compilation of potentially active faults, their distribution, timing, and size of recent surface faulting. Data will be used to make a 1:500,000 map with text.

Utah Zeolites. Compilation of existing data on zeolite deposits in Utah. Mapping, sampling, deposit characterization of large occurrences.

Earthquake hazards: Wasatch Front. Compilation of available data on earthquake hazards along the Wasatch Front.

Rockfall hazards: Wasatch Front and Cache County. Compilation and mapping at 1:24,000 of rockfall-prone areas.

Cleats in Utah coals. Cleat and joint measurements, interpretation; regional trend maps; evaluation of existing mine designs in relation to known cleat orientation.

County geologic mapping. Complete mapping and evaluation at 1:100,000 and publication.

Antelope Island geologic mapping. A complete, detailed geologic study of Antelope Island; to be published as a map and bulletin.

Petroleum geology of Grand County. As part of a county study, detail the activity and potential as well as subsurface geology.

Hingeline Study. A USGS cooperative study on the evolution of sedimentary basins and the Wasatch Front, Wasatch Plateau, and the Colorado Plateau.

Hazards bibliographic compilation. Earthquake, rockfall, landslide, problem soils, shallow ground water, flooding, etc. information is collected, verified, and entered in a computerized database for quick reference.

Utah Conference on the Potential Indoor Radon Hazard

Wednesday, June 21, 1989
8 a.m. to 5 p.m.
State Office Building Auditorium

Sponsored by the Utah Geological and Mineral Survey, the Utah Bureau of Radiation Control, and the University of Utah Research Institute.

Objective

This conference will provide a forum for public education by presenting a non-technical overview of current radon research. Topics will emphasize factors affecting Utah and the Rocky Mountain region. Major topics to be considered will include a definition of the basis for current concern, and will trace the course of public and professional involvement from detection of the potential hazard through prevention or mitigation.

Scope

A 1-day symposium will be held in Salt Lake City in mid-June, 1989. The audience will be drawn primarily from the non-technical public of the Wasatch Front region who desire to obtain more information on this recently publicized potential health hazard. Admission will be free, but a modest charge will be made for a volume of symposium talks.

GSA Fact Sheets

The GSA sends out information flyers of a geoscience nature which they call "Fact Sheets." The latest one, titled *Hydrology* is a good example of the genre: a basic, layman level, thorough explanation of the hydrologic cycle, its possible contamination, the means by which various parts of it are measured and explored, and a simplified set of illustrations. They are well written, informative, useful tools for teachers, science writers, and interested people in general.

Contact:
Geological Society of America
Communications Department
P.O. Box 9140
3300 Penrose Place
Boulder, CO 80301

UGMS Staff Changes

Cynthia Brandt, petroleum geologist and Sample Library Manager, has changed course to become Management Systems Analyst at University Hospital. The job combines her interests in computer systems and accounting to make cost accounting at the hospital a bit easier — our best wishes.

The Mapping Section has two new geotechs on a temporary basis, but *Michael Wright* and *Vajdieh Marxen* are already in full swing.

Jean Muller swapped her position as secretary for Economic/Mapping to stand behind a terminal for Eastern Airlines.

Our new monetary manipulator is *Werner Haidenthaller,* recently from the Legislative Auditor General's office. He is still trying to see over the stack of accumulated paperwork on the Accounting Officer's desk — good luck!

Michael Laine, late of Applied Section, has gone over to Oil, Gas and Mining for full-time work.

Venturing a little too near the Yawning Chasm, Grand Canyon, Arizona, U.S.A. Photo from the UGMS archives.

CORRECTION:

The full names of the following people were inadvertently omitted in the Acknowledgements section of *Geologic effects of the 14 and 18 August, 1988 earthquakes in Emery County, Utah,* SURVEY NOTES, Spring/Summer 1988, p. 13:

Sharon A. Jacobsen, of Emery, Guy Seeley, who resides in Clawson, and Darrell V. Leamaster, Castle Valley Special Service District.

This omission does not mean that their contribution to the report is less appreciated; Sharon provided significant rockfall distribution evidence, Guy noted a rockfall produced by an 18 August aftershock, and Darrell provided photographs and spring data which were essential to the report.

GREAT SALT LAKE LEVEL

Date (1988-9)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Aug 01	4208.05	4207.25
Aug 15	4207.60	4206.90
Sept 01	4207.40	4206.55
Sept 15	4207.05	4206.20
Oct 01	4206.85	4206.00
Oct 15	4206.70	4205.90
Nov 01	4206.60	4205.65
Nov 15	4206.50	4205.60
Dec 01	4206.50	4205.60
Dec 15	4206.45	4205.60

Source: USGS provisional records.

UTAH DEPARTMENT OF NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

Address correction requested

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SURVEY NOTES

VOLUME 22 NUMBER 4 WINTER 1988
UTAH GEOLOGICAL & MINERAL SURVEY

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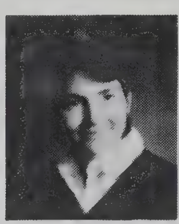
Cover design by Patti Frampton

Survey Notes is published quarterly by **Utah Geological and Mineral Survey**, 606 Black Hawk Way, Salt Lake City, Utah 84108 (801) 581-6831. The UGMS inventories the geologic resources of the state, identifies its geologic hazards, disseminates information concerning Utah's geology, and advises policymakers on geologic issues. The UGMS is a division of the Department of Natural Resources. Single copies of Survey Notes are distributed free of charge to residents within the United States and Canada. Reproduction is encouraged with recognition of source.



FROM THE DIRECTOR'S CORNER

This issue of *Survey Notes* highlights radon ... an odorless, colorless, rather insidious gas that emanates from soil and rocks virtually everywhere and which, when breathed in high concentrations, is a significant cause of lung cancer. Scientists agree that radon is a health problem but don't yet know at what concentrations it becomes a serious hazard or how to avoid the hazard.

Doug Sprinkel's *Survey Notes* lead article explains Utah's radon hazard as we know it today, and what the State and individuals are doing about it. Unlike most chemical hazards emitted into air or discharged into water, radon occurs naturally. As a constituent of earth's atmosphere, it was here long before man arrived. But our recognition of it and its risks are relatively recent. Radon infiltrates every home to some degree. Construction practices and, to an even greater extent, life style habits affect risk ... smoking and radon are a lethal combination.

The UGMS and other scientific organizations are faced with the problem of alerting society to the radon hazard before scientific research has provided an understanding of the hazard and reached consensus on the most effective ways to reduce the risk. Some information that has been released to the public has been criticized as misrepresenting the hazard and causing undue concern. Doug's article attempts to describe the radon hazard in Utah as it currently is understood, and also points out the gaps in our knowledge. His article also includes statements such as "work continues and more information becomes available ... the map can be used only as a guide ... not much is known about ..." etc. Bedrock characteristics, hydrology, and geologic structure appear to be significant factors controlling distribution of the hazard, and a better understanding of the hazard requires further research in geology, geochemistry and geophysics.

Scientists are faced with the dilemma, more so than with other geologic hazards, of translating technical information about radon hazards to laypeople even though they themselves don't entirely understand the geologic considerations. Radon's quasi-unpredictable distribution is compounded by the problem of making measurements that accurately reflect exposure to the hazard. For instance, radon concentrations fluctuate dramatically with weather conditions and may vary widely within an individual home. How can a short article present the risk in a simplified way that acknowledges the danger without overly alarming the public?

Recognition of the radon hazard is still in its infancy. It eludes easy delineation. Even highly "susceptible" areas include isolated low radon concentrations. As our knowledge of the geologic processes that control radon's distribution improve, the hazards map shown in this issue of *Survey Notes* will change, probably significantly.

SOCIETY'S RESPONSE

In some areas of the United States, society's initial response to the radon hazard, unlike its response to many other geologic hazards such as earthquakes or landslides, has been through banking and lending institutions that have incorporated radon inspections into property transactions, much like termite inspections. Apparently, the risk to property values motivates society even more effectively than exhortations about the health risk. Clearly, incorporating the expense of geologic hazards into the economy encourages individuals to personalize the risk and take actions to reduce it.

Continued on next page.

UGMS' ROLE

One of UGMS' primary goals is to identify Utah's geologic hazards. Another is to better understand Utah's geology. Radon provides excellent opportunities to do both at the same time because, as we come to understand the relationship of bedrock geology, surficial geology, geologic processes, hydrology, and geologic structure, it is as if we are solving several simultaneous equations, concurrently. For instance, radon emanates along active faults. At present, we use faults to delineate the radon hazard, but we also discover buried faults by determining patterns of radon concentrations.

Several UGMS geologists have varying degrees of interest and expertise in Utah's radon hazard. Doug Sprinkel has been UGMS' primary contact with Utah's Division of Environmental Health. Barry Solomon, a recent addition to UGMS, will specialize in determining the causal relationship of geology and hydrology to measured high radon concentration and will work with state and county health officials. In addition, UGMS' ongoing geologic mapping program continues to provide basic bedrock and surficial materials information as new areas of the state are mapped and to relate this information to geologic hazards, including radon. Clearly, there is much to be better understood ... the location of the hazard, the geologic processes that increase and decrease risk, the interaction of rock, soil, water, and geologic structures. As the radon hazard becomes better understood, so will UGMS' role and the net result will be a better understanding of Utah's geology as well as a better basis on which to reduce risk.

UGMS staff and other Utahns received awards for their "accomplishments in fostering the implementation of measures to reduce losses due to earthquakes in the state of Utah," on behalf of the Utah National Earthquake Hazards Reduction Program.

Palmer DePaulis, Mayor, Salt Lake City
Jerald S. Lyon, Deputy City Engineer, Dept. of Public Works, Salt Lake City

Mayor DePaulis' administration has been active in preparing the city for a damaging earthquake by commissioning studies to evaluate the seismic resistance of city buildings and funding strengthening/relocation where necessary. One example is the base isolation retrofit of the City-County building.

Jerry has headed up Mayor Depaulis' seismic upgrade program and has seen that seismic considerations are incorporated into all new construction and remodeling, begun the work of retrofiting critical facilities, and been instrumental in moving critical services (such as fire and police) to safer quarters.

Craig V. Nelson, Salt Lake County Planning
Mike Lowe, Davis County Planning
Robert M. Robison, Utah County Planning

The three Wasatch Front county geologists have been a major factor in facilitating the implementation of loss reduction measures through their close work with planners and local government officials. They have worked closely together and with the UGMS to ensure uniform approaches to loss reduction along the Wasatch Front, and maintained contacts with researchers to see that the most current information is used.

Wendy Hassibe, USGS
Janine Jarva, UGMS

As editors of the Wasatch Front Forum, *Wendy and Janine have contributed to the dissemination of information which is so vital in implementing loss reduction measures. Both have spent much time and effort in soliciting contributions, tracking research, and maintaining the Forum as a useful vehicle for the transfer of timely information.*

William R. Lund, UGMS

Bill has worked closely with Dave Schwartz, Mike Machette, Allan Nelson, and Steve Personius of the USGS in Wasatch fault trenching studies, and coordinated the joint UGMS/USGS trenching work of 1986 and subsequent joint trenching projects along the Wasatch fault. He handled logistical arrangements, organized field trips, and is presently organizing a program to publish the results. The field trips held to inform local government officials and the press of the results of the studies have contributed greatly toward their understanding of earthquake hazards and the science involved in assessing hazards.

Fred E. May, Utah CEM

Fred has been instrumental in implementing CEM's earthquake program through his advice to communities regarding hazards mitigation and his role as Utah's State Hazards Mitigation Officer. He is presently completing a handbook to aid local governments in assessing risks and estimating losses due to earthquakes.

Assessing the Radon Hazard in Utah

by
Douglas A. Sprinkel

INTRODUCTION

Most geologic hazards are the result of natural dynamic processes that continue to shape and alter the landscape. Many times these processes affect property and lives, as Utahns were recently reminded by the 1980s debris flows, debris floods, landslides, and rise of Great Salt Lake which together cost the citizens of Utah hundreds of millions of dollars. Some of these geologic hazards are peculiar to Utah because of the state's regional and geologic setting, and some are common throughout the country. Radon, a radioactive gas formerly thought of largely as an occupation health hazard among underground uranium miners, has now been found in many buildings throughout the country in higher concentrations than anticipated. The Environmental Protection Agency estimates about 5,000 to 20,000 Americans will die each year from lung cancer caused by long-term radon inhalation (EPA, 1986). This concern for the health consequences associated with long-term exposures to elevated indoor radon levels has prompted scientists and health officials to assess the radon hazard and determine the extent of the problem.

Everyone receives some low-level radiation generated from naturally occurring radioactive isotopes found in nearly all rocks, soils, and water. We are also subjected to a certain amount of cosmic radiation that penetrates the earth's protective atmosphere everyday. The amount and distribution of terrestrial and cosmic radiation vary with altitude and location, but it occurs throughout the environment in small quantities. The daily external and internal dose of natural radiation that the general population receives poses a low health threat.

Terrestrial concentrations of radioactive isotopes are not uniformly distributed in rocks and soils. Some areas have elevated levels of radioactivity because of the geology. Nero (1986) pointed out that scientists began discovering elevated levels of natural radiation in many areas of the world from measurements taken to monitor background radiation levels near nuclear power plant sites. Concern of the scientific community grew over the potential consequences of exposures to elevated levels of naturally occurring radioactive isotopes.

Discussions of exposure to natural radiation and its apparent health effects began in the early 1960s and continued into the 1980s (Adams and Lowder, 1964; Adams and others, 1972; Gesell and Lowder, 1980; Vohra and others, 1982). Nero (1986) also noted that an increasing awareness of an apparent health risk from exposure to elevated levels of indoor radon began in the mid-1970s as a result of research conducted in Sweden. Scientists were also becoming aware of the potential health risks associated with locating building sites on uranium or uraniferous phosphate mill tailings or using uranium tailings as back-fill materials (NCRP, 1984a). Still, most of the health concern for the general population was focused on the potential exposure to significant sources of radiation from nuclear power plants.

Scientists were recently reminded that certain rock types do significantly contribute to elevated indoor radon levels. In 1984, a worker at the Limerick nuclear power plant in Pennsylvania repeatedly set off the radiation alarms in the plant (Nero, 1986). The source of the radiation was found to be his radon-contaminated home in Boyertown, Pennsylvania, which has one of the highest recorded levels of indoor radon in the United States. This area of Pennsylvania is within a geologic province called the Reading Prong consisting of metamorphic rocks that happen to have above-average concentrations of uranium. These rocks were the source for the radon found in the worker's home (Smith and others, 1987). This revelation reinforced what some scientists suspected and prompted other investigators to reexamine areas of similar geologic units. Investigations have identified other rocks types that typically contain above-average concentrations of uranium (Phair and Gottfried, 1964; Richardson, 1964; Rogers, 1964; Heier and Carter, 1964; Otton, 1988). These rocks, such as black, organic-rich shales and granites, are now primary candidates as sources of elevated levels of radon. From preliminary work conducted in some states, the Environmental Protection Agency (EPA, press release August 1986 and August 1987) suggests that areas of the United States underlain by certain rock types (metamorphic rocks, granites, black shales) have a greater likelihood of having elevated levels of indoor radon than areas underlain by other rock types (figure 1). However, rock type alone doesn't always indicate the areas that have elevated levels of indoor radon. Other geologic considerations such as permeability and porosity of the soil, water saturation of soils and rocks, and ground water play a role in determining probable hazard areas. Non-geologic considerations such as weather conditions, building construction, construction materials, and life styles directly influence indoor radon levels. Understanding geologic and non-geologic components and how they interact with radon, and the short-lived radon decay products, will significantly contribute toward an increased ability to assess areas of Utah more likely to have elevated indoor radon levels.

Little is now known about the extent of indoor radon levels throughout Utah. However, indoor radon measurements collected within the past few years in limited areas suggest that certain localities in Utah may be susceptible to elevated levels (Woolf, 1987). Lafavore (1987) shows about 15% of homes tested in Utah exceeded the EPA action level (EPA measurement protocols are discussed later in this article) of 4 pCi/l (4 picocuries per liter of air). Other studies (Rogers, 1956, 1958; Tanner, 1964; Horton, 1985; Sprinkel, 1987) addressed only Utah's outdoor radon occurrences in soil and water, or identified the distribution of certain rock types that may contribute to an indoor radon problem. There are two concurrent strategies that guide investigators in their attempt to determine the magnitude of the potential radon hazard in Utah. They are (1) determine the distribution

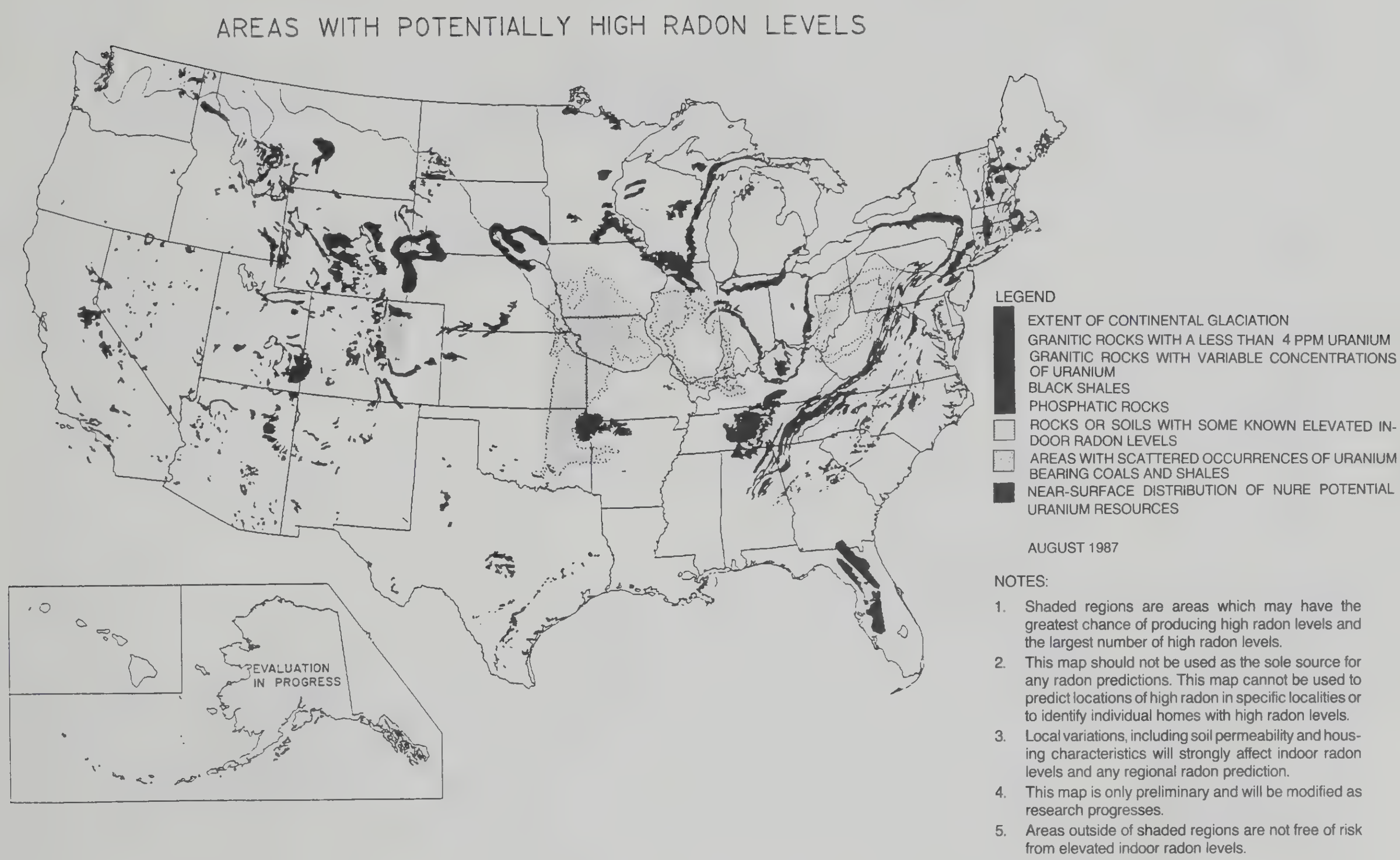


Figure 1. *Distribution of areas in the United States the Environmental Protection Agency (EPA) identifies with potential high radon levels. These areas delineate certain rock types [found throughout the U.S.] that have the capability of producing greater than average amounts of radon (EPA, press release August 1986 and August 1987).*

and magnitude of elevated indoor radon levels in existing buildings and (2) make geologic observations and develop methods to assess the likelihood of elevated indoor radon levels for undeveloped site-specific localities. Information gained from both approaches will supplement one another and provide a much clearer picture of the radon hazard in Utah.

RADON AS A HAZARD

Three questions commonly asked about radon as a hazard are (1) what is radon, (2) why is radon considered a hazard, and (3) why wasn't radon recognized as a hazard before now? To better understand radon as a potential hazard and the geologic factors that influence radon hazard assessments, a brief discussion of radon and radiation is necessary.

What is radon? Radon is an ordorless, tasteless, and colorless radioactive gas which forms in three radioactive series found in nature. The most common decay series where radon is present is the uranium (^{238}U) decay series where uranium decays to form stable lead (^{206}Pb) (figure 2). As new isotopes form through spontaneous disintegration they emit alpha, beta, and gamma radiation. Radon (^{222}Rn) is part of the uranium decay series and forms directly from the disintegration of radium (^{226}Ra). During radioactive decay a sequence of radon progeny forms. The radon progeny are short-lived radioactive products which mostly emit alpha and beta radiation (figure 2). Two other isotopes of radon (^{219}Rn and ^{220}Rn) occur in nature and may contribute to the indoor radon problem. For the purpose of this article the source of the potential hazard only includes radon (^{222}Rn) because it is the most abundant of the radon radioactive isotopes and it has the longest half-life of 3.825 days. Future references to radon in this article imply ^{222}Rn and the ^{238}U decay chain.

Radon occurs in nature and, similar to its parent isotopes radium and uranium, is found in nearly all rocks and soils in small concentrations. Most sources of radiation are solids. Radon is a gas that is generally chemically inert and very mobile. These characteristics give radon the ability to move with the air (or dissolved in water) through cracks and other open spaces in rocks and soils. Radon normally escapes into the atmosphere in small concentrations. However, large concentrations of radon may exist when favorable geologic conditions are present.

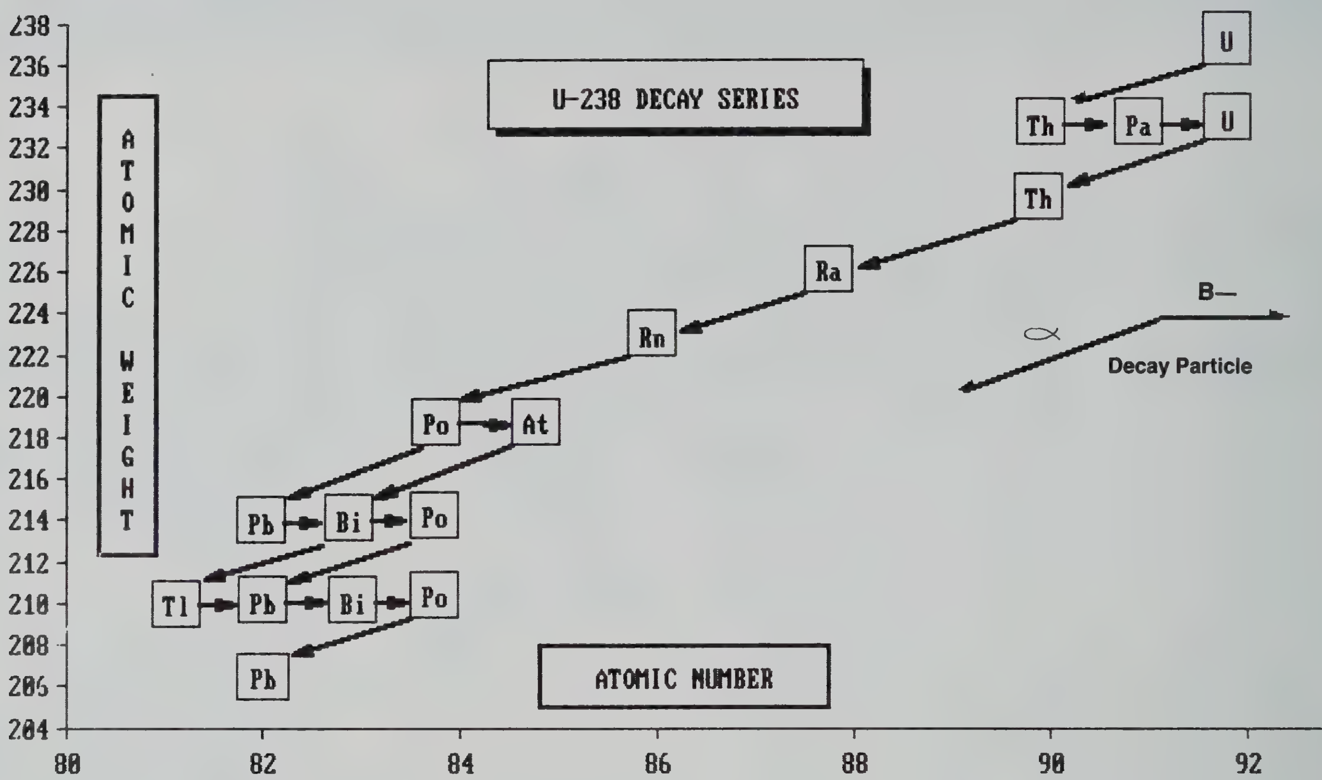


Figure 2. *Uranium (^{238}U) decay series. Radon (^{222}Rn) is derived from radium (^{226}Ra) and is the only isotope in the series that is a gas. Because it is also inert, radon has the ability to move along with air or water (modified from Durrance, 1986).*

Why is radon considered a geologic hazard? Radon is a hazard because it is derived from geologic materials. In addition, geology influences local radon concentration, release, and migration. As mentioned earlier, radon and other sources of natural radiation occur most everywhere in small concentrations. Most of the natural background radiation a person receives daily is low-level external and internal doses that are not considered to be a general health threat. But health officials believe breathing elevated levels of radon over time increases the risk of inducing lung cancer because of the internal radiation to the lungs from decaying radon and radon progeny (Jacobi and Eisfeld, 1982; NCRP, 1984a, 1984b).

Radon concentrations in the atmosphere never reach dangerous levels because air movement dissipates the radon. People are more likely subjected to the risk of the radon hazard in buildings (homes, schools, office buildings) or natural enclosures with poor air circulation. The exposure to the hazard, in most cases, is dependent on non-geologic factors such as building condition and life styles.

Radon can find its way into buildings through small basement cracks or other foundation penetrations. It is in buildings, or other enclosures with poor air circulation, that radon can be trapped and begin to concentrate. Sextro (1988) cited a recent study by Nero and others (1985) which showed that nearly all homes tested in the United States contain some radon (figure 3). The EPA (1986) estimates the average indoor-radon concentration is about 1 pCi/l (1 picocurie per liter of air). Maximum radon concentrations are often in basement levels or low crawl spaces (Fleischer and others, 1982) because these parts of a house are in contact with the ground which is the primary source of radon and not because radon is denser than air. Still, indoor levels in most buildings generally are low.

Inhalation of radon alone is not thought to be the direct source of internal radiaiton because radon does not attach itself to the lining of the lungs. In addition, most of the inhaled radon atoms are exhaled before they decay and emit dangerous alpha particles to lung tissue. The radioactive isotopes formed from radon decay are of more concern because they are not inert and do readily attach themselves to the first charged surface they contact. In other words, the short-lived radon progeny produced from radon decay will become attached to the nearest particle in the air. Typically, these particles are common dust or smoke found in all homes. Households (or offices) with people who smoke place the occupants at greater risk because the home (or building) usually contains a greater percentage of particles in the air, which provides more opportunity for radon progeny to become attached than in smoke-free homes.

The dust or smoke particles with radon progeny attached

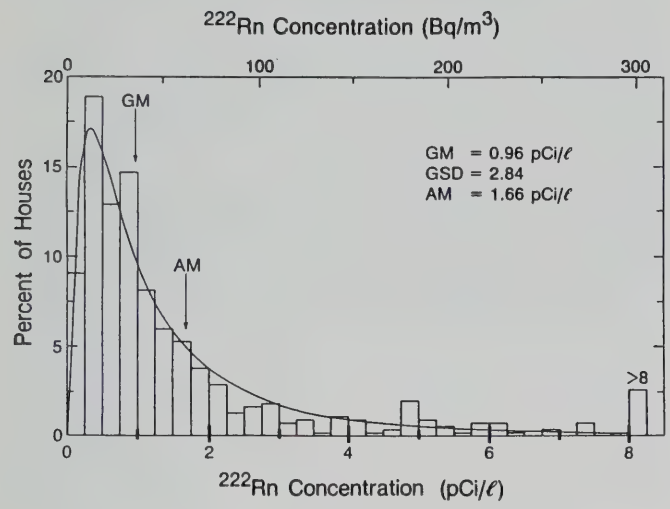


Figure 3. *The actual distribution of radon concentrations in the U.S. is unknown, but this frequency distribution estimates the probable distribution of ${}^{222}Rn$ concentrations based on 552 U.S. homes surveyed. The smooth curve is a log normal function with the parameters shown. The geometric mean (GM) is about 0.9 pCi/l, the geometric standard deviation (GSD) is 2.8, and the average (AM) is 1.6 pCi/l (from Sextro, 1988).*

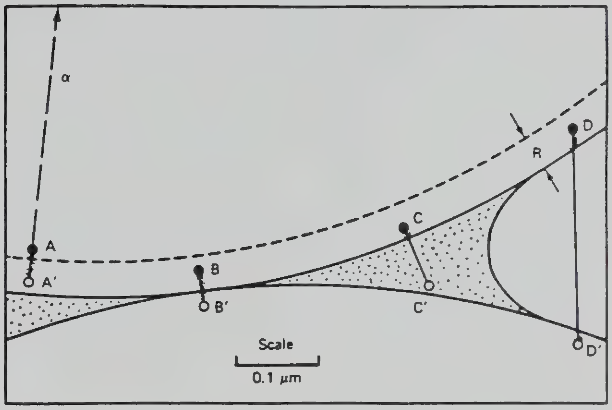


Figure 4. *Idealized cross section of two grains and how radon can escape (the emanation process). The two grains are in contact near B. The stippled pattern represents a miniscus film of water between grains. The white area to the right of the water is air. Radium-226 atoms are represented by the solid dots and radon-222 atoms are the open circles. R is the recoil distance of the newly formed radon atom. Because of the small recoil distance of radon within the grain, only radium atoms found near the grain's surface would contribute to radon emanation. Recoiling radon atoms passing through a film of water are more likely to remain in the pore space, while radon atoms that pass only through air may become embedded in the adjoining grain and rendered harmless (from Tanner, 1980).*

become lodged in the lining of the lungs when inhaled. Once lodged, the resident time in the lungs for these particles is greater than the cumulative half-life of the radon progeny. This allows tissue to be directly bombarded by a series of energetic alpha particles as the radon progeny decay (table 1).

Why has radon only recently received national attention as a hazard found in homes? Scientists had earlier suspected inhalation of radon and radon decay progeny as a health problem in the late 1950s and early 1960s when investigations were conducted on miners who worked in underground uranium mines. The studies concluded that high concentrations of radon found in underground uranium mines significantly contributed to an increased incidence of lung cancer among miners (NCRP, 1984b). What focused the attention of indoor radon to homes was the discovery in 1984 of high levels of radon within a home near Boyertown, Pennsylvania. Prior to that most scientists believed that indoor radon problems were associated with homes built on uranium mill tailings (NCRP, 1984a) or uraniferous phosphate processing waste. The lower concentrations of uranium (or radium) found in a variety of rocks were assumed not to contribute to significant levels of radon indoors. But the association of elevated indoor radon levels with the lower concentrations of uranium (or radium) found in various rocks, such as granites or black, organic-rich shales, was surprising. The potential for elevated levels of indoor radon are now associated with rock having average uranium concentrations less than 15 ppm (parts per million) (Durrance, 1986). Many areas of the country, including much of Utah, are underlain by rock which could be responsible for producing elevated indoor radon levels.

Changes in building practices over past 15 years have also contributed to the radon problem today. Since the 1973 oil embargo, conservation of our non-renewable energy resources has been a national goal through energy-efficient practices. The building industry has done an exceptional job of making structures more energy efficient. However, they have not improved adequate ventilation systems to accommodate for restricted natural air flow. Buildings, including single-family homes, constructed before 1973 often did not use energy-efficient measures, allowing indoor air to escape through above-grade joints, attic, and uninsulated walls. This amount of ventilation often prevented indoor radon levels rising to critical concentrations. Today, most homes are built with energy-efficient standards in place which prevents the loss of indoor air to the outside. Studies (Fleischer and others, 1982; Nero and others, 1982) have shown that energy-efficient buildings with under-designed ventilation systems generally have higher indoor radon levels compared with conventional buildings.

GEOLOGIC CONSIDERATIONS

For radon to be a problem it must build up to elevated concentrations within homes or buildings where people reside. Tanner (1986) suggested four ingredients must be met in order to have an indoor radon problem. The home (1) must be built on ground that contains radium, (2) has underlying soils that promote easy movement of radon, (3) has porous building materials or openings below grade, and (4) has lower atmospheric pressure inside. Thus, the ground must contain a certain amount of radium from which radon emanates. Radon has to travel easily through the soil to the structure before it decays. The structure must have foundation cracks or spaces in contact with the ground and have a lowered atmospheric pressure inside to allow radon to enter. Domestic water and home construction materials also contribute to indoor radon levels. However, the major contributor of radon, in most cases, is the geologic materials immediately underlying the home.

The first geologic consideration is the distribution of rocks that may contain uranium (or radium) in unusually high concentrations. Areas underlain by rock such as granite, metamorphic rocks, some volcanic rocks, and black, organic-rich shales (plus other sedimentary units) are generally associated with a potential indoor radon hazard. Later in this article the distribution of these rock types in Utah are discussed. If the radioactive source rock is present in the ground, there are several geologic considerations that enhance or impede radon emanation and movement. Most of these factors are observable and measurable in the field. The results of initial geologic work can be a foundation for understanding radon behavior for that particular geologic terrain and the impetus for more detailed investigations. Many of the principles and techniques used to detect radon emanation and migration were first developed for uranium exploration during the uranium boom three decades ago (IAEA, 1976). Radon hazard assessment uses the same principles and techniques but different levels of sensitivity.

Once radium is present in the mineral matter of the rock or soil, the radon formed must escape the crystal structure or surface films of the mineral grain. It does so during the spontaneous decay of radium where an alpha particle and a radon atom are given off. The radon atom recoils in the opposite direction of the alpha particle. Radon atoms near the grain's surface may recoil and end up in the pore or burrow into an adjacent mineral grain (figure 4). Because the newly produced radon atom has a small recoil distance, grain size, pore size, porosity, and moisture content are important components in radon emanating power (Tanner, 1964, 1980; Barretto, 1975). Emanating power is defined as the fraction of radon atoms that escape from the solid where they were formed (Tanner, 1980).

Tanner (1964, 1980) and Barretto (1975) discussed the inverse relationship between grain size and emanating power. Grains larger than 1 micron can retard radon recoil since the recoil distance is less than the grain size and radon atoms produced deep in the grain's interior are unlikely to escape. Only radon atoms near the grain's surface have the opportunity to escape, thus reducing the amount of available radon atoms. Tanner (1980) also points out that small pore size can reduce emanat-

Isotope	Symbol	Half-Life	Decay Particle	Energy (MeV)
Uranium	U-238	4.468 billion years	a	4.195 4.14
Thorium	Th-234	24.1 days	b	0.192 0.10
Protactinium	Pa-234m	1.18 minutes	b	2.31
	Pa-234	6.7 hours	b	2.3
Uranium	U-234	248,000 years	a	4.768 4.717
Thorium	Th-230	80,000 years	a	4.682 4.615
Radium	Ra-226	1602 years	a	4.78 4.59
Radon	Rn-222	3.825 days	a	4.586
Polonium	Po-218	3.05 seconds	a, b	6.0
Astatine	At-218	2 seconds	a	6.7 6.65
Lead	Pb-214	26.8 minutes	b	0.7 1.03
Bismuth	Bi-214	19.7 minutes	a, b	a=5.5 b=3.2
Polonium	Po-214	0.000164 seconds	a	7.68
Thallium	Tl-210	1.32 minutes	b	5.43
Lead	Pb-210	22.3 years	b	0.015 0.061
Bismuth	Bi-210	5.02 days	a, b	a=4.7 b=1.16
Polonium	Po-210	138.3 days	a	5.3
Lead	Pb-206			

Table 1. *Uranium decay series showing the half-lives of isotopes. Radon's half-life is less than four days and the radon progeny combined half-life is about 90 minutes.*

a=alpha
b=beta

ing power because the recoiling radon can pass through the pore space and become embedded in the adjacent grain.

Another factor that influences radon production is the water that occupies the space between the grains. Tanner (1980) discussed the fact that a little water coating the grains can increase radon emanation. When radon recoils from the grain it can pass through a dry pore space and become imbedded in the adjoining grain and rendered harmless. However, if the grain has a thin coating of moisture, the moisture can absorb the recoil energy of the radon atom and the radon is more likely retained in the pore space. So moisture doesn't increase the rate of radon production, but it allows a higher percentage of recoiling radon atoms to remain in the pore space.

Once radon occupies the pore space of the rock or soil, it has the ability to move. Radon migration results from two mechanisms, diffusion and mass transport. It was once thought that most of the radon movement through the rock or soil column occurred by diffusion (the random movement of radon atoms by natural vibration). However, the distance radon can travel by diffusion in about four days is negligible (Barretto, 1975). Because measurements of high concentrations of radon in some areas are unaccountable by diffusion alone, Tanner (1964) suggests that mass transport of radon by the convective flow of soil gas is the primary mechanism to move large quantities of radon through the ground. Convective flow of soil gas is caused by air pressure differences within the soil, or between the soil and atmosphere, or between the soil and foundation of a structure. Air pressure differences can be caused by barometric pressure changes in the atmosphere, wind blowing across a surface, or thermal convection generated by heating or cooling. These processes go on in nature and affect the release of radon from the soil, however they also affect radon levels within a structure. Home heating and wind conditions can create localized low pressure inside a home, allowing it to be an effective pump drawing in underlying radon-laden soil gas. Recent discussions (Clements and Wilkening, 1974; Tanner, 1980) imply that both diffusion and flow are active in radon migration. However, one mechanism may dominate another at different times during migration.

Water saturation of soil or rock columns can effectively inhibit the migration of radon. A little water increases radon emanation; however, a lot of water restricts radon migration by reducing diffusion and blocking flow of soil gas (Tanner, 1980). Radon may move with the water, but the flow of water through soil and rocks is much slower. However, Tanner (1980) does note that water is an effective means to carry radon from its rock source. Where domestic water sources contain high levels of radon, they may contribute to indoor radon levels. Thermal waters and the deposits they derive (tufa) are also likely sources of radon.

Permeability and porosity of the rock or soil column influences radon's ability to get to the surface. There appears to be a correlation between areas that have permeable soils and elevated indoor radon concentrations (Tanner, 1980; Schery and Siegel, 1986). Measuring radon concentrations over large areas can also identify buried fault zones. Monitoring changes in radon concentrations on active fault zones, such as the San Andreas fault zone, or in volcanically active areas may serve as a possible indicator of future geologic activity such as earthquakes or volcanic eruptions (Tanner, 1980; King, 1986; Teng and Laing, 1986; Thomas and Cuff, 1986).

POTENTIAL RADON HAZARD AREAS IN UTAH

Not much is known about the location and distribution of indoor radon levels in Utah. However, there are several areas in Utah that may have the proper geologic setting for a radon hazard. Sprinkel (1987) mapped potential radon hazard areas in Utah. These areas were identified on the basis of distribution of known uranium occurrences (possible point sources for radon) and uranium-enriched rocks (generalized sources) found at the surface or beneath well-drained, porous and permeable soils. Uranium occurrences have been previously described by Hintze (1967), Doelling (1969), Chenoweth (1975), Silver and others (1980), Gurgel and others (1983), Stevens and Morris (1984). Included are uranium mines, uranium occurrences, uranium mill sites, geothermal and other thermal areas. Uranium-enriched rocks have been described by Durrance (1986). Distribution of these rock types (as well as other rock types) were mapped by Hintze (1980). Sprinkel (1987) did not include Quaternary units in the compilation unless reported in publication (Stevens and Morris, 1984), nor major fault zones as hazard areas.

Additional work has revealed other areas of Utah which are likely candidates for a radon hazard. This work (figure 5) includes the location of the Wasatch fault zone based on published geologic maps (Scott and Scroba, 1985; Davis, 1983a, 1983b, 1985; Personius, 1988). In addition, a map of apparent surface concentration of uranium (Joseph S. Duvall, unpublished map, 1987) outlines the distribution of uraniferous rocks not shown by geologic mapping.

Figure 5 represents a composite map showing areas in Utah currently thought to have a greater chance of having a radon hazard based on geologic data. It is only a guide to help state health officials, interested decision-makers, developers, and the public determine areas for indoor radon measurements. The patterned areas primarily represent generalized outcrop patterns. The boundaries of these areas are imprecise and may change with future, detailed, study. Non-patterned areas between closely grouped patterned areas may eventually fill in, forming belts of generalized sources. Areas of low radon potential may occur within patterned areas. As work continues and more information becomes available, modifications to radon hazard areas depicted on the map (figure 5) are inevitable. It is important to remember that this map only addresses some of the geologic considerations that influence the location of the indoor radon hazard. Other considerations such as movement of radon through soil, permeability, condition of the building foundation, and lower indoor atmospheric pressure are not represented.

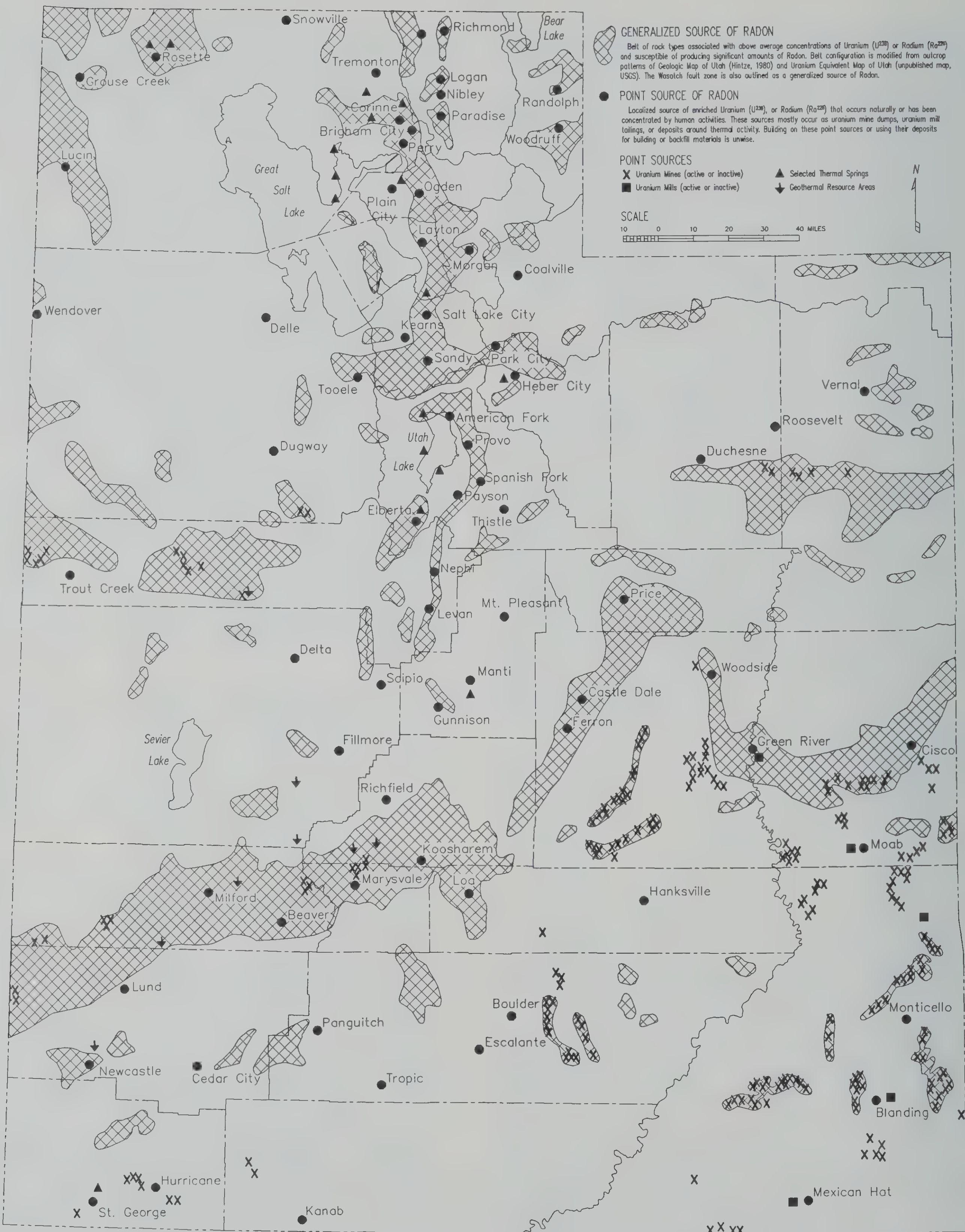


Figure 5. Generalized radon potential map of Utah (modified from Sprinkel, 1987).

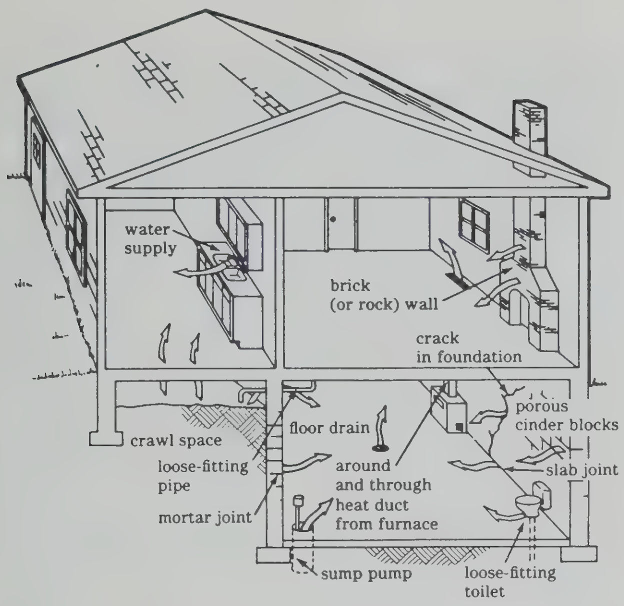


Figure 6. *Various pathways for radon to enter a home. Most of the entry routes are in the basement, since that's the part of the house with the greatest surface area exposed to the surrounding soil. The most common pathways are through cracks and spaces around pipes, sump holes, floor drains, and the joint between the floor and walls. The gas can also enter the house dissolved in the water (reprinted from* Radon: The Invisible Threat© *by Michael Lafavore. Permission granted by Rodale Press, Inc., Emmaus, PA 18049.*

DETERMINING INDOOR RADON LEVELS

Even though a building (or home) is within an area identified as being a potential radon hazard, it may not have an elevated level of indoor radon. Conversely, a building located in an area with no obvious geologic indicators may have high indoor radon levels. Non-geological factors, such as foundation condition, building ventilation, building material used, life styles, etc. influence indoor radon levels. However, average indoor radon levels in areas where favorable geologic conditions exist are consistently higher than other areas. As discussed earlier, the primary source of most radon found in a building generally comes from the underlying geologic materials. The radon enters the building through below-grade foundation cracks or penetrations, such as utility pipes (figure 6). Because of the influence of non-geologic factors on indoor radon concentrations, presently the most conclusive means to determine if a specific building has a radon problem is to measure radon concentrations in the building. There are several methods to measure radon. They include short-term and long-term passive detectors and electronic instruments. Some may be placed by the homeowner, others require a private company. Most people want to have information quickly so they often select short-term monitoring which gives quick, accurate results. However, long-term monitoring may provide more realistic information and may prevent unnecessary costly modifications to the building.

Measurements taken over a few days or on single day will provide only a snapshot of indoor radon levels for that particular time. Radon concentrations in the ground fluctuate daily, weekly, and monthly because of meteoric changes (Kramer and others, 1964; Schery and Gaeddert, 1982). Indoor radon levels also respond to changing weather conditions. In addition, concentrations can fluctuate seasonally because buildings are more closed up in the winter than summer. Indoor heating and air conditioning also affect concentrations. A longer period of monitoring (twelve month period) is generally recommended to smooth out short-term fluctuations. This will provide a more realistic picture of the yearly average indoor radon concentration for that building. Ronca-Battista (1988) discussed radon measurement protocols suggested by the Environmental Protection Agency to assure accuracy and consistency of data. They were developed to balance the need to obtain results quickly and acquire the best possible measurement which best reflects the long-term indoor radon levels. Ronca-Battista (1988) also indicates that a short-term measurement is any test conducted less than three months regardless of the type of detector used. The Utah Bureau of Radiation Control in Salt Lake City provides specific information on the different types of radon detectors available, their advantages and disadvantages, and comparative cost.

Most buildings throughout the United States will contain some radon, but concentrations are usually less than 3 pCi/l (3 picocuries per liter of air). Long-term exposure to these levels are generally considered a small health risk to the general population. Figure 7 shows the risk posed by various levels of radon. A picocurie (pCi) is the decay of about 2 radon atoms per minute. Thus 10 pCi/l represent the decay of about 22 radon atoms per minute in one liter (about one quart) of air. Another unit of measurement often used to report concentrations are working levels (WL). This is different from a picocurie because it is a unit of measurement of radon decay product concentrations. One working level (WL) is defined as the quantity of short-lived radon decay products that will result in 1.3 x 10^{-5} Mev (million electron volts) of potential alpha energy per liter of air (EPA, 1987).

To determine, as accurately as possible, the indoor radon levels throughout the home, long-term monitoring is needed on each floor. EPA (1986) and Ronca-Battista (1988) suggest, however, that a short-term screening measurement which follows EPA protocol (closed-house conditions) may be conducted in the lowest livable area of the house to determine if additional or follow-up testing is necessary. According to EPA (1986) additonal testing is not needed if the short-term screening measurement is less than 4 pCi/l and, although a small health risk is present, remediation is unnecessary. If a result is greater than 4pCi/l and less than 20 pCi/l, a follow-up test of a 12-month measurement in two living areas of the house is recommended by EPA (1986). If retesting confirms screening measurements, mitigation may be warranted in a few years. If a screening measurement is greater than 20 pCi/l and less than 200 pCi/l, retesting is recommended in two living areas of the house for no more than three months (EPA, 1986). If a screening measurement is confirmed, remediation should take place within the next several months. If a screening measurement is over 200 pCi/l, retest immediately in at least two living areas of the house (EPA, 1986). If confirmed, remedial action should

Figure 7. *Radon risk evaluation chart. Different people perceive their risk to geologic hazards differently. The EPA has developed this chart to provide comparable risks for people to evaluate their personal risk to the radon hazard (EPA, 1986).*

Radon Risk Evaluation Chart

pCi/l	WL	Estimated number of lung cancer deaths due to radon exposure (out of 1000)	Comparable exposure levels	Comparable risk
200	1	440—770	1000 times average outdoor level	More than 60 times non-smoker risk; 4 pack-a-day smoker
100	0.5	270—630	100 times average indoor level	20,000 chest x-rays per year
40	0.2	120—380		
20	0.1	60—210	100 times average outdoor level	2 pack-a-day smoker
10	0.05	30—120	10 times average indoor level	1 pack-a-day smoker; 5 times non-smoker risk
4	0.02	13—50		
2	0.01	7—30	10 times average outdoor level	200 chest x-rays per year
1	0.005	3—13	Average indoor level	Non-smoker risk of dying from lung cancer
0.2	0.001	1—3	Average outdoor level	20 chest x-rays per year

EPA, 1986 OPA 86-004 Fig. 6

commence within several weeks. Similarly, the Utah Bureau of Radiation Control follows these guidelines but emphasizes the value in long-term monitoring (D. Finerfrock, personal comm., 1987). Ronca-Battista (1988) recently outlined current EPA measurement protocols. They appear to emphasize immediate short-term, follow-up testing in two living areas of homes with screening measurements greater than 20 pCi/l.

CURRENT PROGRAMS ASSESSING THE POTENTIAL RADON IN UTAH

The Utah Bureau of Radiation Control, an agency within the Department of Environmental Health, is conducting a survey to assess indoor radon levels statewide. The study involves the participation of about 750 volunteers in several cities throughout the state where elevated indoor radon levels are thought to occur. These homes had to be owner-occupied single-family dwellings. Terradex Corporation provided the Alpha Track-Etch© radon detectors and the Bureau of Radiation Control asked the volunteers to leave the device in their homes for twelve months. The initial distribution of the radon detectors occurred in the fall of 1987. The monitoring period will end in the final quarter of 1988 and preliminary survey results should be compiled in the early part of 1989. The Utah Geological and Mineral Survey cooperated with the Bureau of Radiation Control by providing geologic information (Sprinkel, 1987) to help select areas in the state that might be likely candidates for elevated indoor radon levels. This information was the basis for soliciting volunteers in critical areas of the state. The information derived from this study will provide state health officials with the first indication of the extent of Utah's indoor radon problem. The study will also provide the Utah Geological and Mineral Survey with valuable information required to examine the relationships between geology and indoor radon levels.

The Utah Geological and Mineral Survey believes that conducting a statewide survey is essential in understanding the potential extent of an indoor radon problem. The Utah Geological and Mineral Survey is also interested in determining methods to geologically characterize an area for potential radon problems and produce usable information for health officials, decision makers, developers, and the general public. Our cooperation with the Bureau of radiation Control is an important part of that goal. Additionally, the Utah Geological and Mineral Survey, in cooperation with the University of Utah Research Institute is conducting an investigation on Antelope Island to add to the understanding of the geologic factors that influence radon occurrence, emanation, and migration. Antelope Island was selected because detailed geologic mapping (Doelling and others, 1988) is available and it consists of a variety of metamorphic, igneous, and sedimentary rocks that have been structurally complicated. Understanding the potential radon hazard of Antelope Island will hopefully aid in any future site selection of permanent island residences. The geology on the island is similar in some respects to that of the Davis and Weber Counties and this study will also aid in the greater understanding of potential radon hazard of this part of the highly populated Wasatch Front urban corridor.

SUMMARY

Radon is a new environmental concern throughout the country because of its suspected link to lung cancer. Radon is an odorless, tasteless, and colorless radioactive gas that occurs in nearly all rocks and soils. It is found in most buildings in small enough concentrations that it is generally not considered a health threat. However, scientists have recently discovered certain geologic conditions that influence the likelihood of having elevated indoor radon levels in buildings. Because of the complex relationships between geologic and non-geologic factors that control radon levels, predicting radon concentrations from building to building is difficult. The current understanding of radon behavior prohibits extrapolating radon values over any distance. But with additional indoor radon surveys and geologic characterization of sites, discovering critical combination of components will lead to an easier and reliable radon assessment. It is important to assess indoor radon levels in Utah and determine the extent of the problem statewide. It also is equally important to determine the critical factors that contribute to the potential radon hazard of an undeveloped area. The use of that information by health officials, decision-makers, developers, and the public may facilitate mitigation techniques into building design before developing an area.

ACKNOWLEDGEMENTS

Understanding radon as a hazard is complex and integrates several scientific disciplines including geology, physics, chemistry, and health physics. I am greatful to the scientists who, through discussions, provided valuable insight into the various aspects of radon. I thank Hellmut H. Doelling (UGMS) and Don R. Mabey (formerly UGMS, USGS) for technically reviewing the Generalized Radon Potential Map of Utah. Their suggestions were extremely beneficial in developing the map. I am also indebted to the following for taking time to review this manuscript; their efforts are appreciated and significantly improved this paper. They include Dane Finerfrock, Utah Research Institute; Miriam H. Bugden, Utah Geological and Mineral Survey; John S. Hand, Utah Geological and Mineral Survey; and Genevieve Atwood, Utah Geological and Mineral Survey. I would like to especially thank James K. Otton of the U.S. Geological Survey for taking the time to review this manuscript, for his guidance and suggestions were particularly helpful.

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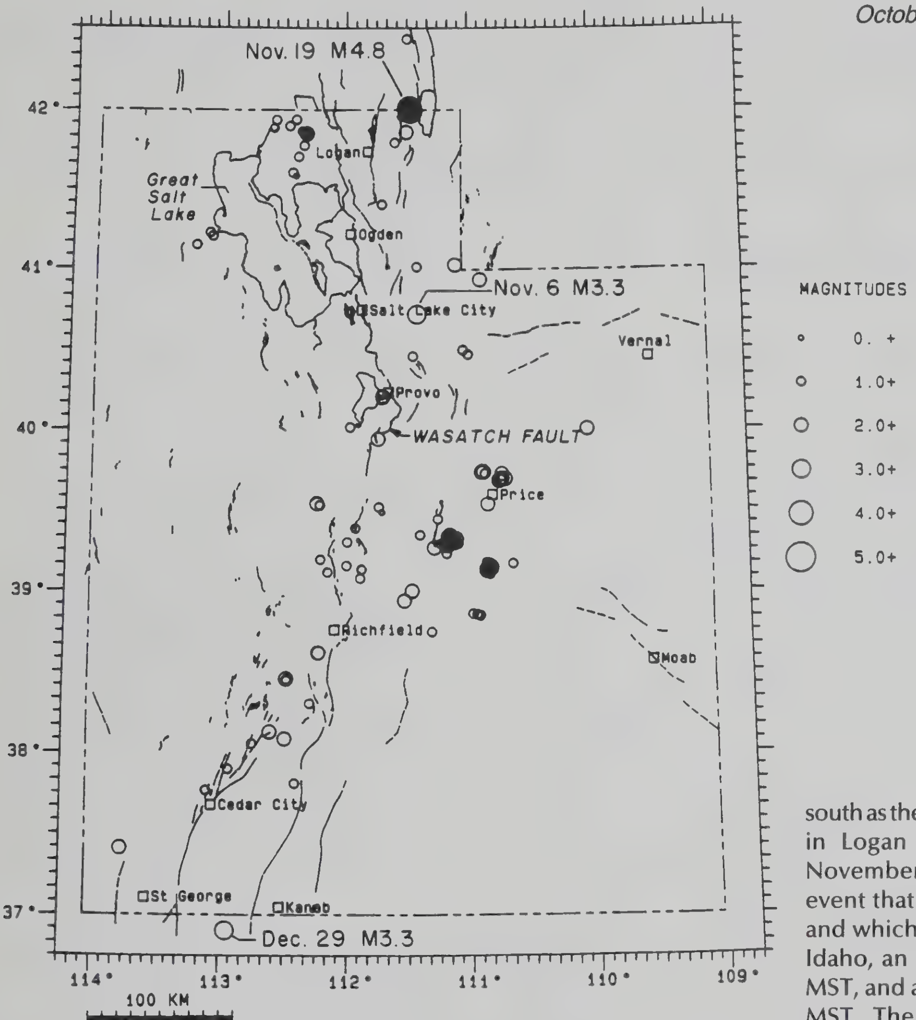
Utah Earthquake Activity

by Susan J. Nava
University of Utah Seismograph Stations, Department of Geology and Geophysics

October 1 — December 31, 1988



During the three-month period October 1 through December 31, 1988, the University of Utah Seismograph Stations located 245 earthquakes within the Utah region (see accompanying epicenter map). Of these earthquakes, 80 had a magnitude (either local magnitude, M_L, or coda magnitude, M_C) of 2.0 or greater, five had a magnitude of 3.0 or greater, and six were reported felt.

The largest earthquake during the report period was a shock of M_L 4.8 on November 19 at 12:42 PM MST on the Utah-Idaho border, 5 km west of Bear Lake, in northern Rich County. The Bear Lake earthquake was felt widely in northern Utah and southern Idaho (Modified Mercalli Intensity IV to V), and as far south as the Salt Lake Valley. Minor damage was reported in Logan and Ogden, Utah. Aftershocks of the November 19 Bear Lake earthquake include an M_L 4.3 event that occurred 18 minutes after the main shock and which was felt in northern Utah and in southern Idaho, an M_L 3.2 shock on November 28 at 3:46 AM MST, and an M_L 2.8 shock on December 2 at 11:46 AM MST. The latter two were felt by residents in nearby small towns. During the report period, 50 earthquakes associated with the Bear Lake sequence have been located.

Two other earthquakes of magnitude 3.0 and greater occurred in the Utah region during the report period: one of M_L 3.3 on November 6 at 8:30 AM MST, located 9 km NNE of Park City, Utah, and reported felt as far away as the Salt Lake Valley; and another of M_C 3.3 on December 29 at 11:18 AM MST, located 40 km SW of Kanab, Utah. One additional earthquake was reported felt in Utah during the report period: an M_L 1.8 event on October 28 at 4:10 PM MDT, felt in West Valley City.

Additional information on earthquakes within Utah is available from the University of Utah Seismograph Stations.

Geo-Calendar

Meeting information is as accurate as we can make it. Listings may be sent to Survey Notes Editor, *but we're picky.*

Apr. 6-7 GSA SOUTHEASTERN SECTION MEETING in Atlanta. Contact J.A. Whitney, Dept. of Geology, University of Georgia, Atlanta, GA 30602, (404) 542-2652.

Apr. 5-7 SOCIETY OF PETROLEUM ENGINEERS REGIONAL MEETING, Bakersfield, CA. Contact SPE, Box 833836, Richardson, TX 75083-3836. (214) 669-3377.

April 7 FIBERS, FIBERS, FIBERS, sponsored by Society of Mining Engineers in Baltimore, MD. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162. (303) 973-9550.

Apr. 20-21 GSA NORTH-CENTRAL SECTION meeting in Notre Dame. Contact Michael J. Murphy, Dept. of Earth Sciences, Univ. of Notre Dame, Notre Dame, IN 46556, (219) 239-6686.

Apr. 23-26 AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS 74TH ANNUAL CONVENTION, San Antonio, TX. Contact AAPG, Box 979, 1444 S. Boulder, Tulsa, OK 74101. (918) 584-2555.

May 3-5 CALIFORNIA MINING ASSOCIATION ANNUAL MEETING AND INDUSTRY EXHIBITS, in Sacramento. Contact California Mining Association, 1010 11th Street, Suite 213, Sacramento, CA 95814, (916) 447-1977.

May 3-5 WESTERN SURFACE COAL MINING MEETING, Gillette, Wyoming. Contact Meetings Dept., SME, P.O. Box 625002, Littleton, CO.

May 7-10 ROCKY MOUNTAIN AND CORDILLERAN SECTIONS, GSA JOINT MEETING held in Spokane, WA. Contact Sandra Rush, GSA Communications Dept., P.O. Box 9140, 3300 Penrose Place, Boulder CO 80301; (303) 443-8489.

May 20-24 FOURTH U.S. NATIONAL CONFERENCE ON EARTHQUAKE ENGINEERING, in Palm Springs, CA. Contact Dee Czaja, 4NCEE, Civil Engineering Dept., Univ. of California, Irvine, CA 92717, (714) 856-8693.

June 5-7 INTERNATIONAL GOLD-SILVER CONFERENCE IX, in Sparks, Nevada. Contact Dr. Yung Sam Kim, Nevada Institute of Technology, P.O. Box 8894, Reno, NV 89507, (702) 331-0607.

June 8-10 ELKO MINING EXPO '89 at the Elko Convention Center in Elko, NV. Contact: Kay Thompson, Elko Convention and Visitors Authority, 700 Moren Way, Elko, Nevada 89801. Phone 1-800-248-ELKO.

June 11-15 RAPID EXCAVATION AND TUNNELING, sponsored by the Society of Mining Engineers, at the Bonaventure Hotel in Los Angeles. Contact: Darline Daley, Society of Mining Engineers, P.O. Box 625002, Littleton, CO 80162. (303) 973-9550.

June 15-16 WYOMING MINING ASSOCIATION CONVENTION in Rock Springs. Contact: Wyoming Mining Association, Hitching Post Inn, P.O. Box 866, Cheyenne, Wyoming 82001. Phone (307) 635-0331.

June 19-22 AMERICAN MINING CONGRESS COAL CONVENTION '89 in Pittsburgh. Contact: the American Mining Congress, Suite 300, 1920 N Street, Washington, DC 20036. (202) 861-2821.

June 22-25 NATIONAL COAL ASSOCIATION ANNUAL MEETING in White Sulphur Springs, West Virginia. Contact: National Coal Association, 1130 17th Street N.W., Washington, DC 20036. (202) 463-2625.

July 9-19 28TH INTERNATIONAL GEOLOGICAL CONGRESS, Washington, D.C. For information contact Bruce B. Hanshaw, Box 1001, Herndon, VA 22070-1001, (703) 648-6053.

July 30-Aug. 2 SOIL AND WATER CONSERVATION SOCIETY 44TH ANNUAL MEETING in Edmonton, Alberta, Canada. Contact Alfred Birch, 7515 N.E. Ankeny Road, Ankeny, IA 50021.

Aug. 13-23 FRIENDS OF THE PLEISTOCENE, ROCKY MOUNTAIN CELL, 1989 FALL FIELD TRIP. Contact Pete Birkeland, Dept. Geological Sciences, Campus Box 250, Univ. of Colorado, Boulder, CO 80309.

Sept. 7-9 INTERNATIONAL GOLD EXPO, sponsored by the Engineering and Mining Journal, at Bally's Convention Center in Reno. Contact: Industrial Presentations, Inc. 12371 East Cornell Avenue, Aurora, CO 80014. (303) 696-6100.

Sept. 10-14 EDITING INTO THE NINETIES. Joint meeting at the Westin Hotel in Ottawa, Canada of Council of Biology Editors, European Assn. of Science Editors, Assn. of Earth Science Editors, and National Research Council of Canada. Contact Ken Charbonneau, Executive secretary, National research Council of Canada, Ottawa, Canada K1A OR 6, (613) 993-9009.

Sept. 10-14 WYOMING GEOLOGICAL ASSOCIATION 40TH FIELD CONFERENCE. Contact Lynette George, 2220 Volcaro Rd., Casper WY 82604 (307) 265-0775 or Stephen Hollis, PO Box 1068, Casper WY 82602 (307) 577-7460.

Sept. 25-28 SIAM CONFERENCE ON MATHEMATICAL AND COMPUTATIONAL ISSUES IN GEOPHYSICAL FLUID AND SOLID MECHANICS in Houston. Contact SIAM, 14th Floor, 117 So. 17th St., Philadelphia, PA 19103. (215) 564-2929.

Oct. 1-6 ASSOCIATION OF ENGINEERING GEOLOGISTS ANNUAL MEETING, Vail, CO. Contact Denver Section, AEG, P.O. Box 15124, Denver CO 80215.

Oct. 23-26 FOURTH INTERNATIONAL CONFERENCE ON SOIL DYNAMICS AND EARTHQUAKE ENGINEERING, in Mexico City, Mexico. Contact A.S. Cakmak, Dept. of Civil Engineering, Princeton University, Princeton, NJ 08544, (609) 452-4601.

Nov. 6-9 GSA ANNUAL MEETING in St. Louis. Contact Sandra Rush, GSA Communications Dept., 3300 Penrose Place, Box 9140, Boulder, CO 80301, (303) 447-8850.

UGMS Publications for 1988

Released from January 1 to December 30, 1988

MAPS

43 *Physiographic subdivisions of Utah,* by W.L. Stokes, 1 pl., 1:2,500,000, 1977 (reprint).

94 *Geologic map of the Pigeon Mountain quadrangle, Box Elder County, Utah,* by L.L. Glick and D.M. Miller, 1:24,000, 9 p., 2 pl, 1987.

95 *Geologic map of the Jackson quadrangle, Box Elder County, Utah,* by D.M. Miller and L.L. Glick, 1:24,000, 7 p., 2 pl., 1987.

103 *Geologic map of the Panguitch NW quadrangle, Iron and Garfield Counties, Utah,* by J.J. Anderson and P.D. Rowley, 1:24,000, 11 p., 2 pl., 1987.

104 *Geologic map of the Little Creek Peak quadrangle, Garfield and Iron Counties, Utah,* by J.J. Anderson T.A. livari, and P.D. Rowley; 1:24,000, 11 p., 2 pl., 1987.

105 *Geologic map of the Marysvale quadrangle, Piute County, Utah,* by P.D. Rowley, C.G. Cunningham, T.A. Steven, H.H. Mehnert, and C.W. Naeser, 1:24,000, 15 p., 2 pl., 1988.

106 *Geologic map of the Antelope Range quadrangle, Sevier and Piute Counties, Utah,* by P.D. Rowley, C.G. Cunningham, T.A. Steven, H.H. Mehnert, and C.W. Naeser, 1:24,000, 14 p., 2 pl., 1988.

108 *Geologic map of the Silver Peak quadrangle, Iron County, Utah,* by M.A. Shubat and M.A. Siders, 1:24,000 13 p., 2 pl., 1988.

110 *Shallow ground water and related hazards in Utah,* compiled by Suzanne Hecker and K.M. Harty, 1:750,000, 17 p., 1 pl., 1988.

111 *Flood hazards from lakes and failures of dams in Utah,* by Kimm M. Harty and Gary E. Christenson, 8 p., 1 pl., 1:750,000, 1988.

55-D *Mineral resources of the southern Wasatch Front, Utah,* compiled by Fitzhugh D. Davis with a section on petroleum by F.C. Moulton and R. L. Kerns, 17 p., 2 pl., 1:100,000, 1988.

55-C *Ground-water resources of the southern Wasatch Front, Utah* compiled by Don Price and L.S. Conroy, 6 p., 3 pl., 1:100,000, 1988.

MISCELLANEOUS PUBLICATIONS

87-2 *Mineral fuels and associated energy resources,* by M.R. Smith, flyer.

87-4 *Industrial Commodities: non-metallic resources of Utah,* by M.R. Smith, flyer.

S *Geology of Utah,* by W.L. Stokes, 305 p., 1986 (reprint).

88-1 *In the footsteps of G.K. Gilbert — Lake Bonneville and neotectonics of the eastern Basin and Range province,* edited by Michael N. Machette, 120 p., 1988.

88-2 *Geology and Antelope Island State Park, Utah,* by H.H. Doelling and others, 20 p., 1988.

88-3 *Geologic consequences of the 1983 wet year in Utah,* by B.N. Kaliser and J.E. Slossen, 109 p., 1988.

CIRCULARS

80 *Annual production and distribution of coal in Utah, 1987,* by A.D. Smith and F.R. Jahanbani, 8 p., 1988.

79 *Suggested approach to geologic hazards ordinances in Utah,* by G.E. Christenson, 16 p., 1987 (reprint).

BULLETINS

122 *Salt deformation in the Paradox region,* by H.H. Doelling, C. G. Oviatt, and P.W. Huntoon, 93 p., 1988.

125 *Geology and mineral potential of the Antelope Range Mining District, Iron County, Utah,* by M.A. Shubat and W.S. McIntosh, 26 p., 2 pl., 1988.

REPORTS OF INVESTIGATION

209 *Scandium-bearing aluminum phosphate deposits of Utah,* by M.A. Shubat, 26 p., 1988.

216 *Technical reports for 1987—Site Investigation Section,* compiled by B.D. Black, 115 p., 1988.

217 *An overview of landslide inventories predominantly in North America,* by Sandra Eldredge, 98 p., 1988.

218 *Technical reports of the Wasatch Front geologists, June 1985-June 1988,* compiled by B.D. Black and G.E. Christenson, 154 p., 1988.

OPEN-FILE REPORTS

82DF *Significant drill-hole data of the Wasatch Front valleys, including Cache Valley and Tooele Valley, Utah,* by W.F. Case and C.D. Burt, 27 p., 1 diskette, 1988.

108 *Potential radon hazard map of Utah,* by D.A. Sprinkel, 3 p., 1:1,000,000, 1987 (revised to September, 1988).

115 *Earthquake response strategies for UGMS and the earth-science community,* by G. Atwood, M. Noonan, W. Case, and D. Mabey, 33 p.

116 *Geology of the Boulder Mountain quadrangle, Cache County, Utah,* by A.R. Mork, 29 p., 2 pl., scale 1:24,000.

117 *Great Salt Lake brine sampling program 1985-1987,* by J. Wallace Gwynn, 30 p., 1988.

118 *Geology of the Gold Hill quadrangle, Tooele County, Utah,* by Jamie Robinson, 33 p., 1 pl., scale 1:24,000.

119 *Geology of the Geyser Peak quadrangle, Sevier County, Utah,* by S.T. Nelson, 37 p., 2 pl., scale 1:24,000.

120 *Geology of the Levan quadrangle, Juab County, Utah,* by W.L. Auby, 56 p., 2 pl., scale 1:24,000.

Continued on next page.

121 *Geology of the Calf Creek quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 21 p., 2 pl., scale 1:24,000.

122 *Geology of the Juab quadrangle, Juab County, Utah,* by D.L. Clark, 54 p., 2 pl., scale 1:24,000.

123 *Geology of the King Bench quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 14 p., 2 pl., scale 1:24,000.

124 *Geology of the Tenmile Flat quadrangle, Garfield County, Utah,* by G.W. Weir and L.S. Beard, 18 p., 2 pl., scale 1:24,000.

125 *Geology of the Red Breaks quadrangle, Garfield County, Utah* by G.W. Weir and L.S. Beard, 18 p., 2 pl., scale 1:24,000.

126 *Geology of the Fountain Green North quadrangle, Sanpete and Juab Counties, Utah,* by R.L. Banks, 78 p., 3 pl., 1:24,000.

127 *Maximum extent of potential flooding due to simultaneous failure of dams in Salt Lake County, Utah,* by W.F. Case, 28 p., 1 pl., 1″ = approximately 1 ¼ miles, 1988.

128 *Quaternary geology of the Black Rock Desert, Millard County, Utah,* by C.G. Oviatt, 53 p., 1 pl., 1:100,000.

129 *Causes of shallow ground-water problems in part of Spanish Valley, Grand County, Utah,* by Robert H. Klauk, 46 p., 1988.

130 *Geologic map of the Antelope Peak quadrangle, Iron County, Utah,* by S.K. Grant and P.D. Proctor, 32 p., 1 pl., 1:24,000.

131 *Sample Library catalog,* by UGMS staff, 374 p.

132 *Acid neutralizing capacity map of Utah,* by William F. Case, 9 p., 1 pl., scale 1:500,000, 1988.

133 *West-central Kane County state lands evaluations for State Lands and Forestry,* by Hellmut H. Doelling, 517 p., 1988.

134 *Geology of the Tule Valley, Utah 30 x 60-minute quadrangle,* by Lehi F. Hintze and Fitzhugh D. Davis, 1 pl.

135 *Thematic mapping applied to hazards reduction, Davis County, Utah,* by B.N. Kaliser, 18 p., 1988.

136 *Preliminary geology of the Red Knolls quadrangle, Millard Co., Utah, by L.F. Hintze and F.D. Davis, 12 p., 1 pl.*

137 *Preliminary geology of the Long Ridge quadrangle, Box Elder Co., Utah,* by L.F. Hintze and F.D. Davis, 11 p., 1 pl.

138 *Geology of the Crater Island quadrangle, Box Elder Co., Utah,* by D.M. Miller, T.E. Jordan, and R.W. Allmendinger, 59 p., 1 pl.

139 *Geology of the Lucin 4 SW quadrangle, Box Elder Co., Utah,* by D.M. Miller, 45 p., 1 pl.

140 *Geology of Calico Peak quadrangle, Kane Co., Utah,* by H.H. Doelling and F.D. Davis, 40 p., 1 pl.

141 Geology of Lampo Junction quadrangle, Box Elder Co., Utah, by D.M. Miller, M.D. Crittenden, Jr., and T.E. Jordan, 49 p., 2 pl.

142 *Geology of the Cannonville quadrangle, Kane and Garfield Counties, Utah,* by R. Hereford, 25 p., 1 pl.

143 *Quaternary geology — Tule Valley, west-central Utah,* by D. Sack, 60 p., 1 pl.

144 *Geology of Antelope Island, Davis County, Utah,* by H.H. Doelling and others, 99 p., 2 pl., 1988.

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Books & Papers

Pay Dirt is a monthly mining magazine meticulously melded from two publications: *Rocky Mountain Pay Dirt* and *Southwestern Pay Dirt*. The former covers Montana, Idaho, Wyoming, Nevada, Utah, and Colorado and tries to cover all the pertinent mining news of interest. If you have an interest in mining, contact Pay Dirt, P.O. Drawer 48, Bisbee, AZ 85603

Annual production and distribution of coal in Utah, 1987, by A.D. Smith and F.R. Jahanbani, 8 p., 1988, UGMS Circular 80. Most of Utah's coal resources are located in the southern and central parts of the state. This circular is a brief summary of the 1987 coal production by county, coal field, and land ownership. It lists historical production from 1980 through the 1988 forecast, and charts the distribution and use of Utah coal, coal imports, exports, and future outlook.

Potential radon hazard map of Utah, by D.A. Sprinkel, 4 p., 1 pl., scale 1:1,000,000 (1" = 17 miles), UGMS Open-File Report 108. This report was revised in September, 1988 from the June, 1987 version and is in the process of being digitized for computer updating (see the lead article in this issue). The title Radon Death Map is ONLY in reference to the people who have to keep updating and redrafting it.

The art of geology, edited by E.M. Moores and F.M. Wahl, Geological Society of America Special Paper 225, 140 p., 1988. The GSA 1988 Centennial brought about a great many things. One was this publication — an unusual departure for GSA, the coffee-table book. Sooner or later, everyone connected with geology has a collection of rocks and photos in their desk (or garage), often as memorabilia, but sometimes purely for the beauty. These are not often shared; geologists tend to the non-sentimental and the nontalkative. This volume, then, represents two things for me: the latent desire (many of us have it) to publish photographs showing geologic beauty, and a sharing among friends of a loose-knit group who try to express how they feel about a profession and a subject.

All photographs were taken by working geologists (hence the incredible proliferation of rock hammers and pens growing in rock), mostly to detail a structural or stratigraphic event. The text is minimal and oriented to non-geologists; the design is exceptionally good, the dust jacket is award level.

The book goes far in explaining why geologists can look at a formation long after they finish the equally fascinating mental scramble of seeing how it got there. We are personally interested in the book for the inclusion of several shots by Grant Willis, UGMS Mapping Section, and for all the shots of Utah geology. Well done.

Physical, soil, and paleomagnetic stratigraphy of the upper Cenozoic sediments in Fisher Valley, southeastern Utah, by S.M. Colman, A.F. Choquette, and F.F. Hawkins, 1988, 33 p.: U.S. Geological Survey Bulletin 1686.

Mineral resources of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado and Daggett County, Utah, by J.J. Connor and others, 1988: U.S. Geological Survey Bulletin 1714-B.

Mineral resources of the Black Ridge Canyons Wilderness Study Area, Mesa County, Colorado and Grand County, Utah, and Westwater Canyon Wilderness Study Area, Grand County, Utah, by R.P. Dickerson, J.E. Case, H.N. Barton, and M.L. Chatman, 1988, 24 p.: U.S. Geological Survey Bulletin 1736-C.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Cottonwood Canyon Wilderness Study Area, Washington County, Utah, by D.E. Detra, J.E. Kilburn, J.L. Jones, and D.L. Fey, 16 p., 1 pl., 1988: U.S. Geological Survey Open-File Report 88-274

Selected hydrologic data for Pahvant Valley and adjacent areas, Millard County, Utah, 1987, by S.A. Thiros, 151 p., 1988: U.S. Geological Survey Open-File Report 88-195.

Analytical results and sample locality map of stream-sediment, heavy-mineral-concentrate, and rock samples from the Steep Creek Wilderness Study Area, Garfield County, Utah, by R.T. Hopkins, R.J. Goldfarb, S.C. Rose, and R.B. Vaughn, 14 p., 1988: U.S. Geological Survey Open-File Report 88-208.

Analytical results and sample locality map of stream-sediment, heavy-metal-concentrate, and rock samples from the Cockscomb and Wahweap Wilderness Study Areas, Kane County, Utah, by D.E. Detra, J.E. Kilburn, J.L. Jones, and D.L. Fey, 28 p., 1988: U.S. Geological Survey Open-File Report 88-368.

The laccolith-stock controversy; new results from the southern Henry Mountains, Utah, by C.B. Hunt, M.D. Jackson, and D.D. Pollard: Geological Society of America Bulletin, v. 100, no. 10, 1988, p. 1657-1659.

Sediment-yield history of a small basin in southern Utah 1937-1976; implications for land management and geomorphology, by J.B. Laronne and Richard Hereford, 1988: Geology v. 16, no. 10, p. 956-957.

Seismic exploration of the crust and upper mantle of the Basin and Range Province, by L.C. Pakiser, 1985: Geological Society of America Centennial Special Volume 1, p. 453-469.

Diagenesis and burial history of nonmarine Upper Cretaceous rocks in the central Uinta Basin, Utah, by J.K. Pitman, K.J. Franczyk, and D.E. Anders, 1988: U.S. Geological Survey Bulletin 1787-D, p. 1-24.

Hydrocarbon potential of nonmarine Upper Cretaceous and lower Tertiary rocks, eastern Uinta Basin, Utah, by J.K Pitman, D.E. Anders, T.D. Fouch and D.J. Nichols, 1986, *in* C.W. Spencer and others, editors, Geology of Tight Gas Reservoirs: AAPG Studies in Geology 24, p. 235-252.

Seismicity map of North America, by E.R. Engdahl and W.A. Rinehart, 1988, scale 1:5,000,000: Geological Society of America Continent-Scale Map 4. The southwest sheet (sheet 1) covers the western U.S. and affords an overview of seismic trends.

Sequential development of a frontal ramp, imbricates, and a major fold in the Kemmerer region of the Wyoming thrust belt, by J.G. Delphia and E.G. Bombolakis, 1988, *in* G. Mitra and S. Wojtal, editors, Geometriews and Mechanisms of Thrusting, with Special Reference to the Appalachians: Geological Society of America Special Paper 222, p. 207-222.

Ground-water resources of the central Wasatch front area, Utah, 1988, by Don Price, 3 plates, 5 page report, scale 1:100,000, UGMS Map 54-C. This is one of a series of maps describing the geology, natural resources and hazards along the Wasatch front. This non-

Continued on next page.

technical report examines the occurrence, availability, and quality of ground water in the bedrock of the Wasatch Mountains and basin fill of the Salt Lake and Tooele Valleys. Discussions and schematic diagrams map the general direction of ground-water flow in the area as well as the dynamics of recharge and discharge of ground water. The map is presented in three plates. Plate 1 shows saturated thicknesses and transmissivity (rate at which water moves through a unit width of an aquifer under a unit hydraulic gradient) of the altitude of potentiometric surfaces from the spring of 1965 to the spring of 1980. Plate 3 delineates the general quality of water in the basin fill and areas of thermal ground water.

Geologic Map of the Thatcher Mountain Quadrangle, Box Elder County, Utah, 1988, by Teresa E. Jordan, Max Crittenden, Jr., Richard W. Allmendinger, and David M. Miller, 2 sheets, 10 page report, scale 1:24,000, UGMS Map 109.

Geologic Map of the Howell quadrangle, Box Elder County, Utah, 1988, by Teresa E. Jordan, Richard W. Allmendinger, and Max D. Crittenden, Jr., 2 plates, 10 page report, scale 1:24,000, UGMS Map 107. Both the Howell and Thatcher Mountain quadrangles are located in northwestern Utah, north of the eastern arm of the Great Salt Lake and less than 10 miles south of the Utah-Idaho border. Dominant topographic features in the study areas include Anderson Hill and Blue Creek Valley in the center, the Blue Springs Hills along the southeast corner, and the West Hills on the northeastern border. The north-south-trending Basin and Range mountains display Mesozoic folding and thrusting, and Cenozoic high- and low-angle faults.

These maps describe the stratigraphic and structural relationships of the Blue Springs Hills and adjoining North Promontory and Promontory Mountains and West Hills. They are part of a series of studies designed to investigate the evolution of the Paleozoic Oquirrh basin and its relationships to Mesozoic and Cenozoic deformation in northern Utah. Current research shows shows rapid thickness changes in the margins of the Oquirrh basin.

The oldest rocks found in the Thatcher Mountain quadrangle are Pennsylvanian Oquirrh Formation sediments. Lithologic characteristics of these and local Permian rocks indicate deposition in the shelf area of the northeastern basin.

The oldest exposed rocks in the Howell quadrangle are Mississippian-Pennsylvanian Manning Canyon Shale sediments. Lithologic characteristics of these and other Paleozoic rocks indicate deposition in the shelf area of the northeastern edge of the basin. Cenozoic rocks include Tertiary sediments and Quaternary alluvium, colluvium, lacustrine and landslide deposits. In addition to structure and stratigraphy, the reports discuss known and potential economic deposits and geologic hazards.

The ***1989 List of Publications*** is now available from the Idaho Geological Survey, Morrill Hall room 332, Univ. of Idaho, Moscow, ID 83843 free of charge.

UGMS Staff

Cory Burt, our digitally dextrous program perverter has opted for the Department of Business Regulation, thereby leaving us menu-dependent types in a quandry.

Marge Porterfield consented to be the new secretary for Mapping and Economic sections while *Cheryl Crockett* has joined us in the new Sales position. Cheryl worked under our former accounting officer, Gwen Anderson, and probably should have been forewarned. Marge's previous experience includes teaching, real estate development, insurance and securities sales, and considerable environmental community involvement.

Archie Smith served as the head of the Economic Section and as the UGMS industry liaison, but has decided to work with his son-in-law as Executive Vice-president of Transoft International; he's obviously excited about all the possibilities, but he plans to keep up his contacts in all aspects of coal.

Our Sample Librarian, *Carolyn Olsen,* has returned with a set of crutches and her old sense of humor from a very serious car accident. She has help with the boxes of core from our new part-timer *Tom Rahn.*

Susan Olig, the new geologist in Applied Section, is finishing up her Masters in structural geology at the University of Utah. She has worked for Dames & Moore as a geologist, primarily investigating seismic hazards. Susan enjoys skiing, gardening and hiking.

Five-year service awards were presented to three UGMS staffers during our last staff meeting. Each received a plaque set in a polished section of variscite, one of the gemstone commodities of Utah. Congratulations to:

Kent Brown, Senior Cartographer, who began in June, 1983;
Ray Kerns, Energy Geologist, who came on in January, 1983;
and to *Grant Willis,* Geologic Mapper, who started in July of 1983.

New Publications From The UGMS

— The latest publications catalog is available upon request—

Geology of the Bear River City quadrangle, Box Elder County, Utah, by M.F. Jensen, 42 p., 1 pl., Open-File Report 145, available for inspection at the UGMS Library.

Geology of the Gunnison quadrangle, Sanpete County, Utah, by S. R. Mattox, 39 p., 2 pl., Open-File Report 146, available for inspection at the UGMS Library.

MINERAL LEASE SPECIAL PROJECTS PROGRAM

by
Douglas A. Sprinkel

The Utah Geological and Mineral Survey (UGMS) formulated a new program in the early part of 1987 which would solicit proposals from the scientific community for geologic projects that would produce publishable results through the UGMS. The Mineral Lease Special Projects Program (MLSPP) was implemented during spring of 1987 with the appropriate approval and the initiation of the first round of informal solicitations. The proposals received competed for funding on geologic merit, expertise of the proposer, and importance to Utah. They were funded from UGMS' budget with mineral lease revenues.

Two rounds of informal solicitation for proposals have been completed with the awarding of 22 contracts for a variety of geologic projects. The first round was held in spring of 1987 followed by a second round in January 1988. Now that the third round of informal solicitation for proposals is underway, it seems appropriate to reflect on the past two cycles and assess the effectiveness and direction of the program.

PURPOSE OF THE MINERAL LEASE SPECIAL PROJECTS PROGRAM

The Mineral Lease Special Projects Program was conceived by Genevieve Atwood (Director, UGMS) and Don Mabey (former Deputy Director, UGMS), at the urging of the UGMS Board, as a means to contract for special types of geologic information which supplemented continuing UGMS programs without adding permanent staff. It has proven to be a great opportunity to advance the ongoing progress of the UGMS mission. The basic objectives of the program are stated in table 1. However, the general purpose of the program is twofold; to acquire new geologic information and to provide a means of accessing existing geologic data and information that would otherwise be lost.

The funding available for the contacts will vary each round. The UGMS depends on a variety of revenue sources to fund its operations and programs. All expenditures are authorized yearly by the Utah State Legislature. State revenues appropriated are generally fixed amounts with the exception of mineral lease funds. These funds are payments made by the mineral industry to the federal government for exploration and production on federal leases within the state. The UGMS receives 2.25 percent of what the state receives. These revenues oscillate as much as 25 percent in a year as production and exploration levels in Utah vary and prices of energy and mineral commodities fluctuate. Prior to about 1982, prices and production of energy resources in the state appeared fairly predictable, permitting the state to forecast with some certainty what mineral lease revenues would be for the upcoming fiscal year. However, with the collapse of oil prices and the subsequent shift away from domestic exploration, the state's financial prognosticators have difficulty in forecasting meaningful revenue estimates and the UGMS management could not adjust expenditures to match revenues particularly when the actual revenues were not known until after the end of the fiscal year. The Mineral Lease Special Projects Program doesn't change the revenue fluctuations, but serves to minimize the impact of the fluctuation on the management of the UGMS program. The result is a pool of funds, which is not known until the end of the fiscal year, available for special mineral lease contracts.

The primary purpose of the program is to obtain geologic data and information from individual scientists and organizations who have invested time and money in geologic investigations in Utah, but have not made the results of these investigations available to the public. It also creates an opportunity for some timely new research in Utah. This is in accordance with the mission of the UGMS which is to inventory the geologic resources of Utah; identify the state's geologic hazards; better understand Utah's geology through mapping of rock formations and their structural habitat; and disseminate geologic information to teachers, decision makers, state and local governments, and the general public in a way that the information will get used. The Mineral Lease Special Projects Program provides the necessary incentive to get existing and new ideas and data published. The UGMS believes this is an innovative way to obtain and make data, information, and ideas on Utah's geology available to the public through publications at a much reduced cost to Utah.

OBJECTIVES OF THE MINERAL LEASE SPECIAL PROJECTS PROGRAM

(1) Engage expertise not currently available in the UGMS.
(2) Build upon the expertise of individuals within the earth science community who have devoted years to understanding certain geologic problems or geographic areas of the state; thereby acquiring information that has the potential of being lost or for a price below what it would cost to acquire it using UGMS staff.
(3) Obtain specific geologic information in neglected areas of the state, or areas not fully understood or not presently being investigated by UGMS staff.
(4) Undertake important short-term projects without increasing UGMS staff.

***Table 1.** Objectives of the Mineral Lease Special Projects program.*

HOW THE PROGRAM WORKS

The UGMS has four scientific programs whose mission is to study and report on Utah's geologic resources (Economic Geology Program) and geologic hazards (Applied Geology Program), better understand Utah's geologic rock units and their history through regional and detailed mapping (Mapping Geology Program), and provide basic geologic information for the general public (Information Program). The emphasis placed on geologic topics can change with each round of informal solicitations. It can be directed at projects specifically related to one of UGMS' geologic programs or include a variety of projects from each program depending on current need or area of interest of the state. The UGMS Management Advisory Group (composed of the UGMS Director, Deputy Director, Special Assistants to the Director, and Geologic Managers) with the advice from the UGMS Board determines the emphasis for each round of informal solicitations, generally in November. They also decide on several topics for geologic projects based on suggestions from the UGMS geologists. These topics usually reflect areas where geologic data has been collected but not released for public use. They also may reflect areas where additional information is needed and not currently being investigated by the UGMS.

An informal solicitation for proposals document is prepared and distributed in January. Proposals are prepared under guidelines provided in the solicitation and may be received by the UGMS until the closing date which is generally in March. Each proposal is reviewed and rated by three UGMS geologists. The proposal reviews and ratings are compiled and the proposals are ranked in April by the UGMS Management Advisory Group. The recommended ranking is presented to UGMS Board in early May, and the Board selects the proposals that will receive funding.

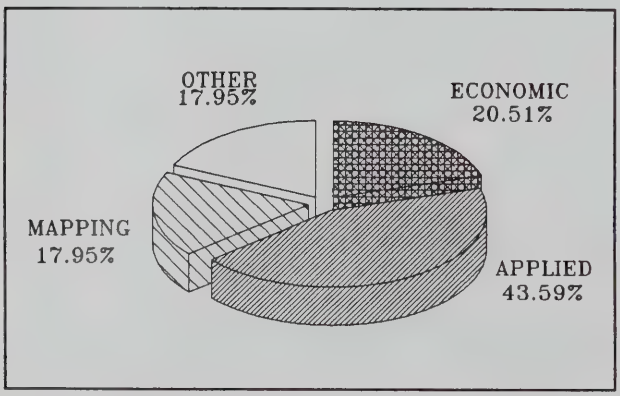

Figure 1. Percentage of proposals received in 1987, by UGMS program.

1987 INFORMAL SOLICITATION FOR PROPOSALS

The 1987 cycle was the first round for the proposals and the UGMS had considerable uncertainty concerning the number and type of response to the solicitation. To encourage as many proposals as possible for this first round, UGMS offered a wide variety of topics in all UGMS programs.

A total of 39 proposals received in 1987 represented a combined amount of about $407,500. The average amount for a proposal was about $10,500. The majority of proposals received were on topics relative to the UGMS Applied Geology program (figure 1). The affiliations of the proposers submitting proposals in 1987 included the academic community, private sector, and governmental agencies. Most of the proposals submitted were from investigators in the academic community (figure 2).

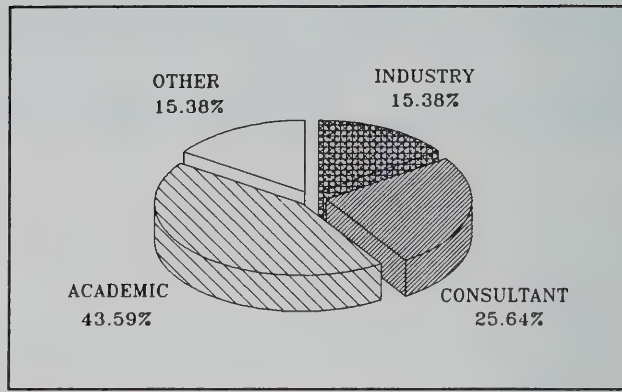

Figure 2. Percentage of proposals received in 1987, by proposer's affiliation.

Out of the 39 proposals submitted, 10 were funded for a total cost of $96,072. The smallest proposal funded was $1,320 and the largest was $16,640 with the average proposal amount being $9,607. Table 2 summarizes the proposals funded in 1987. As noted in table 2, several investigators have completed and submitted their contract products. These products are generally manuscripts, maps, or both which will be published by UGMS as a Miscellaneous Publication (MP publication series) or released to the public as an open-file report (OFR series). The remaining contracted products are expected to be completed and delivered to UGMS sometime during the current fiscal year.

In the 1987 round, the stronger proposals suggested projects to identify geologic hazards or better understand geologic hazard processes. Most were related to earthquake research. Consequently, the majority of funding went to projects dominantly related to UGMS' Applied Geology Program (figure 3). Other proposals funded were projects intended to provide geologic information for the educational community (figure 3). No proposals of a strictly economic geology nature were funded in this round (figure 3).

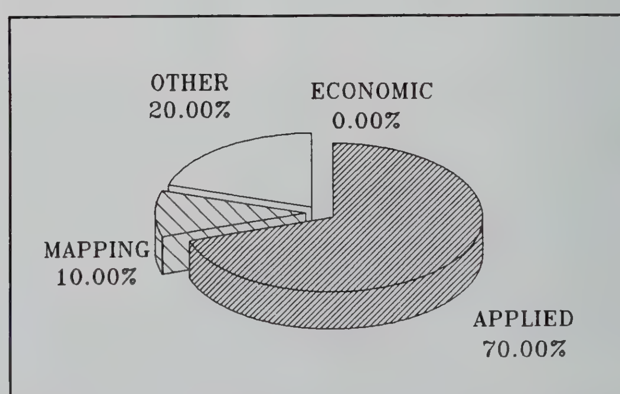

Figure 3. Percentage of proposals funded in 1987, by UGMS program.

Table 2. List of proposal funded in 1987

ML SPECIAL PROJECT TOPICS FUNDED IN 1987.

Modeling of structural and earthquake characteristics of the southern Wasatch fault zone.
R.L. Bruhn; University of Utah
Catalog of Utah metallic ore milling sites.
L.P. James; Consultant
Radiometric dating and correlation of volcanic ash beds of part of the Mesozoic Era.
*B.J. Kowallis; Brigham Young Unversity***
Utah geologic hazards teachers workshop.
*E.H. O'Brien; Utah Museum of Natural History**
Response of collapsible soils to earthquake shaking.
*K.R. Rollins; Brigham Young University**
Subsurface map and seismic risk analysis of the Salt Lake Valley.
*G.T. Schuster, University of Utah**
Geometry and kinematics of normal faults in Utah from seismic reflection data and analytic modeling.
R.B. Smith and H.M. Benz; University of Utah
Use of computer linked remote weather stations to determine the relationship of weather events to slope failures in Davis County, Utah.
*M. Lowe and others; Davis County Flood Control**
A short course in petroleum geology, with examples from Utah's petroleum provinces.
*C.N. Tripp; Consultant**
Liquefaction severity index and hazard map for Utah.
*M.A. Mabey and L. T. Youd; Brigham Young University**

* *Indicates delivery of contracted products*
** *Indicates partial delivery of contracted products*

Most of the proposals funded in the 1987 round were from investigators from the academic community with considerable experience and skill in preparing proposals (figure 4). A distant second were proposals submitted by the consulting community in the private sector and others in local governmental and quasi-governmental organizations (figure 4). The UGMS and the UGMS Board were quite satisfied with the overall results of the 1987 Informal Solicitation for Proposals. The response to the solicitation was greater than anticipated and the quality of most proposals submitted was generally high. Having completed the first round successfully, the UGMS and its Board were eager to begin preparing the 1988 round of informal solicitations and get the Mineral Lease Special Projects program on a regular schedule and formalize the process.

1988 INFORMAL SOLICITATION FOR PROPOSALS

Little modification was incorporated into this cycle. Most of the changes were procedural in nature and went generally undetected outside the UGMS. Some changes were made to ensure internal compatibility with other UGMS programs and policies. The UGMS decided for the 1988 round to not consider proposals submitted by investigators employed with other Utah state agencies and federal agencies where they have existing cooperatives or contractual programs with the UGMS. In addition, guidelines and policies of existing internal programs were incorporated into the 1988 round, such as restricting any multipurpose mapping proposals to a $1,500 cost and discouraging costly proposals over $20,000, to minimize any repercussions or conflicts with other contracting programs in the UGMS.

The UGMS and the UGMS Board were somewhat disappointed by the small response to the solicitation from industry in 1987. They were even more disappointed and concerned that virtually no proposals were funded in 1987 for projects of an economic geology nature. To prevent repetition in 1988, the UGMS and the Board specifically targeted proposals that addressed areas of economic geology in Utah. All proposals submitted to UGMS would be considered, but it was made clear in the solicitation that proposals which addressed targeted topics would receive special consideration.

The Informal Solicitation for Proposals was prepared and distributed in January. The UGMS received 41 proposals by the closing date of March 18, 1988. The sum of all proposals received by the UGMS was about $375,000 in 1988 with the average submitted proposals being about $9,100. Each proposal was independently reviewed by three UGMS geologists and returned to the UGMS Management Advisory Group by the end of April for consideration. The ranked proposals were submitted to the UGMS Board in early May and the top-rated proposals were selected for funding.

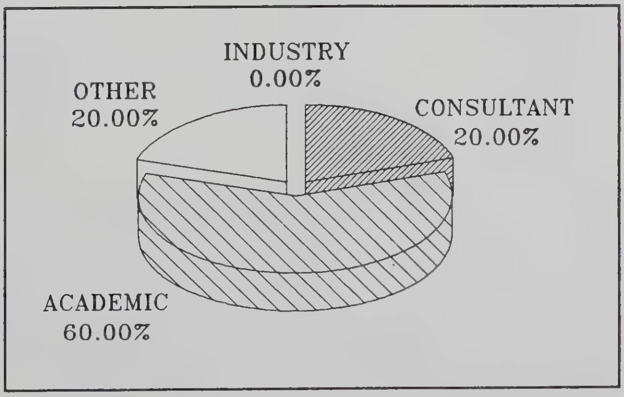

Figure 4. Percentage of proposals funded in 1987, by proposers affiliation.

The proposals the UGMS received in the 1988 round again encompassed a wide variety of topics. However, this time the majority of proposals offered projects of an economic geology nature (figure 5). Most of the projects related to economic geology proposed to investigate the location and geologic habitat of mineral commodities in Utah. Many intended to identify and inventory certain commodities. Others defined the geologic parameters responsible for an occurrence and discussed areas of potential based on observations. A number of proposals offered would provide an insight into Utah's subsurface using well control or the aid of information obtained from geophysical investigations. These proposals intended to define subsurface geometries and geologic relationships which may suggest areas for future exploration. Although these kind of investigations are extremely important to Utah, most of them were not funded because the basic data (seismic lines, gravity data, etc.) to derive interpretations would not be made available to the UGMS to publish. One of UGMS's goals is to prevent the unnecessary loss of valuable data by collecting and being the repository of geologic (and geophysical, geochemical) data in Utah. Hopefully future proposals will indicate these kinds of data will be a part of the proposed products.

The affiliation of proposers submitting proposals once again represented members of the academic community, private sector, and governmental and quasi-governmental organizations (figure 6). Similar to the 1987 round, nearly half of the proposals received by UGMS were generated by members of academia.

Out of the 41 proposals submitted to UGMS, 12 were funded in 1988 for a total of about $106,200. The smallest proposal funded was $4,060 and the largest was $17,500 with the average proposal amount being $8,850.

The emphasis of the 1988 round of informal solicitations was on projects related to economic geology which may lead to economic development of an area in Utah. UGMS and the Board members were diligent in awarding funds to those kind of projects. Figure 7 summarizes the proposals funded in 1988 with about two-thirds of the available funding going to projects that reflect this emphasis. Table 3 summarizes the proposals funded in 1988. From the topic descriptions, there appears to be a fairly even split between petroleum-related and mineral-related projects. All of these projects will contribute important concepts concerning their areas of interest and will add significant data to the state's information base.

The distribution of the proposer's affiliation for the funded projects somewhat mimicked the results of the 1987 round. However, the 1988 round was more successful in attracting proposals from industry. Although a large percentage of funds went to individuals from academia, followed by members of the consulting community, UGMS was able to award a contract to an individual from industry (figure 8). No funds were awarded to proposals that came from governmental or quasi-governmental organizations.

The 1988 round of Informal Solicitation for Proposals was an improvement over the 1987 round in several respects. The timing for future solicitations was established. Modifications in the solicitation and the review process were incorporated that improved the methodology of the selection process. The UGMS received more proposals and funded more projects than in 1987. Finally, the projects funded were directly related to the kind of projects UGMS felt would be important contributions to the state and could possibly initiate economic development in certain areas of Utah.

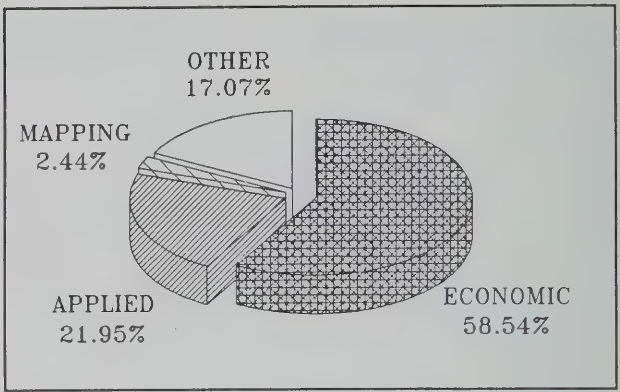

Figure 5. *Percentage of all proposals received in 1988 by UGMS program.*

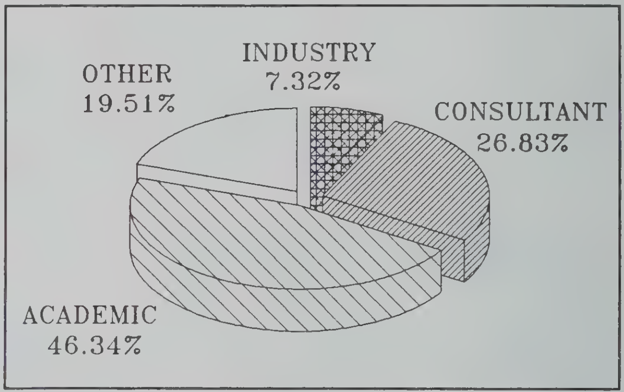

Figure 6. *Percentage of all proposals received in 1988 by affiliation.*

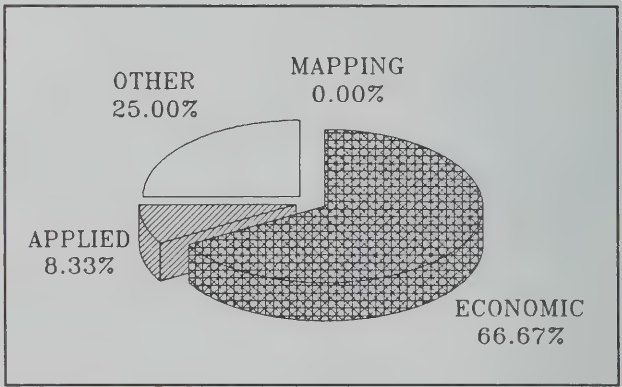

Figure 7. *Percentage of proposals funded in 1988 by UGMS program.*

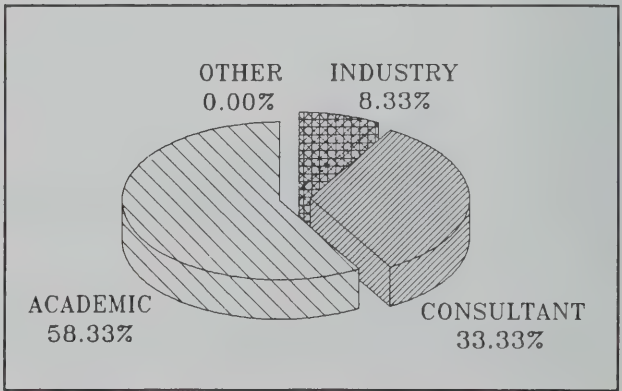

Figure 8. *Percentage of proposals funded in 1988 by affiliation.*

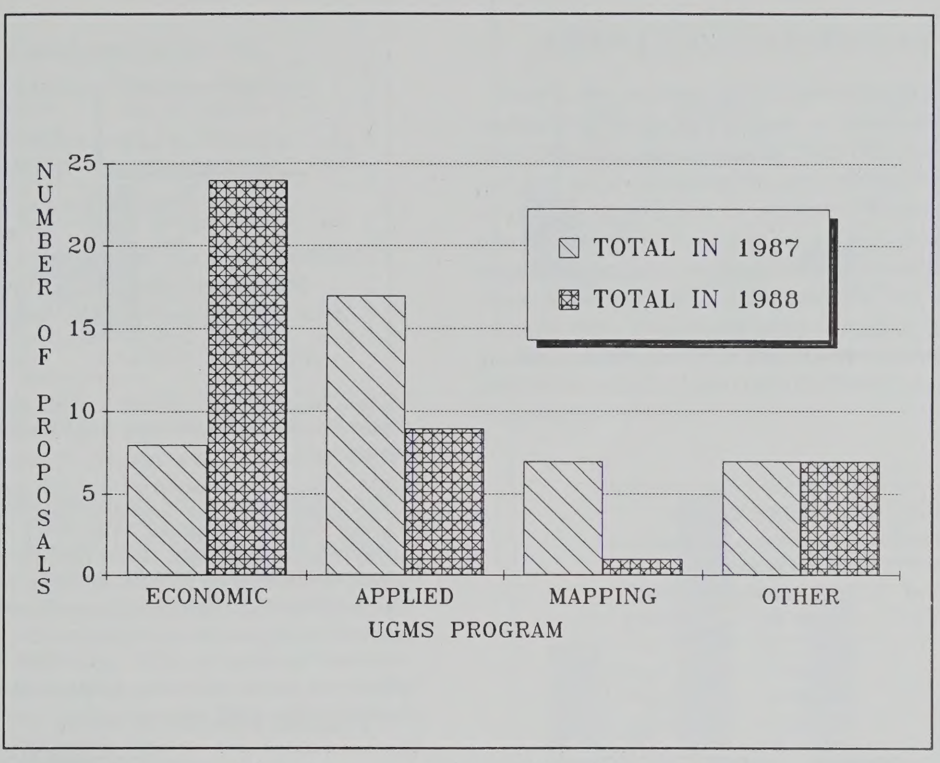

Figure 9. *Comparison of all proposals received in 1987 and 1988 by UGMS program.*

Table 3. *List of proposals funded in 1988.*

1988 ML SPECIAL PROJECTS TOPICS

Eocene-Oligocene history of the East Tintic Mountains, Utah.
J.D. Keith and R.D. Dallmeyer; University of Georgia.

Mineral chemistry of the Beryllium/Yttrium-rich Sheeprock Granite of western Utah.
E.H. Christiansen; Brigham Young University

Dating methods applicable to Quaternary geologic problems in the western U.S.A.
S.L. Forman and G.H. Miller; University of Colorado

A hydrocarbon exploration model (Ferron & Dakota Sandstones) on the Wasatch Plateau, Utah.
C.N. Tripp; Consultant

Petroleum source-rock evaluation.
D.S. Chapman and D. Deming; University of Utah

Geochemical characteristics of black shales related to Mercur-type gold deposits.
W.T. Parry and P.N. Wilson; University of Utah

Oil development and potential of Mississippian formations, San Juan County, Utah.
H.W. Merrell; Consultant

Yttrium resources in Utah.
W.P. Nash; University of Utah

Uranium deposits and potential uranium resources in Grand County, Utah.
H.W. Merrell and W.D. McDougal; Consultant

Potential stratigraphic traps from landward pinch-outs of Cretaceous shoreline facies, Book Cliffs-Wasatch Plateau.
P.B. Anderson; Consultant

Thin-skinned deformation mechanisms of Wasatch Plateau area, Utah.
G.L. Hunt; Cyprus-Plateau Mining

Characterization of ground-water flow systems as related to the proposed "Super Tunnel."
A.L. Mayo; Brigham Young University

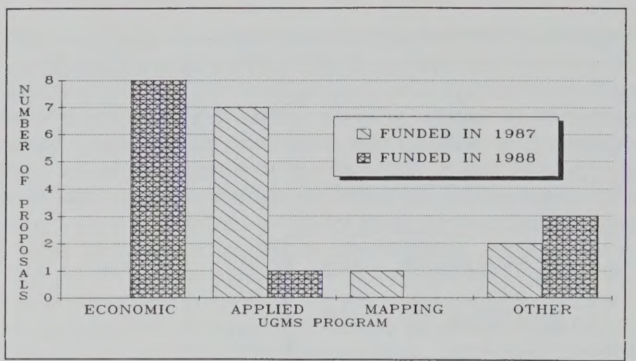

Figure 10. *Comparison of proposals funded in 1987 and 1988 by UGMS program.*

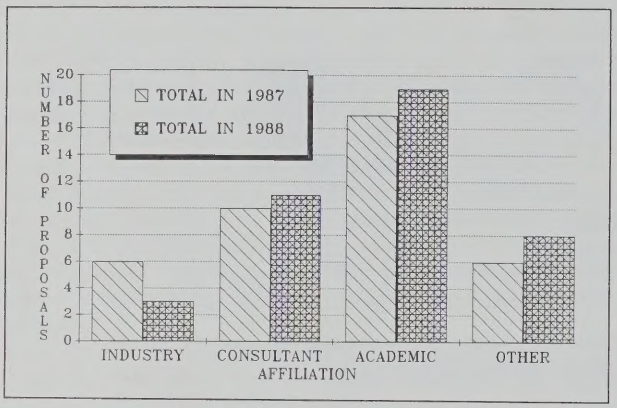

Figure 11. *Comparison of all proposals received in 1987 and 1988 by proposer's affiliation.*

COMPARING THE 1987 AND 1988 ROUNDS

The two rounds of informal solicitations were similar with respect to the number of proposals received, the number of proposals funded, the amount of funds available, and who submitted proposals. The differences between the two rounds directly reflect the change in the UGMS emphasis from one cycle to the next. These changes are mostly related to the kind of projects that will produce information and data which satisfy current needs of the state.

In 1987, most of the proposals received were projects related to UGMS Applied Geology Program, whereas in 1988 the kind of proposals received were dominated by projects related to the Economic Geology Program (figure 9). Because the UGMS indicated that economic geology-related proposals would receive special consideration, the proposers responded accordingly. It is interesting to note that the number of proposals that fell into the "OTHER" category was the same and the Mapping (Mapping Geology Program)-related proposals fell off significantly. The difference in the number of mapping-related projects probably reflects the reduction of award amounts for mapping projects to make them consistent with the existing contracts in the multipurpose mapping program.

A comparison of proposals funded by UGMS program generally reflects the pattern of the relative number of proposals received for that solicitation cycle. Most of the proposals funded in 1987 were related to the Applied Geology Program, and in 1988 the funds generally went to proposals related to the Economic Geology Program (figure 10).

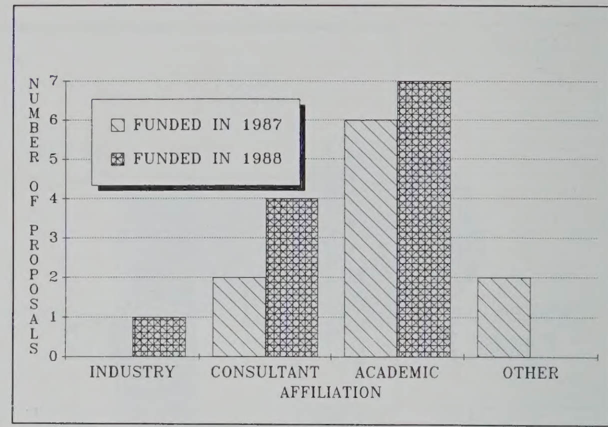

Figure 12. *Comparison of all proposals funded in 1987 and 1988 by proposer's affiliation.*

A comparison of the proposer affiliation in 1987 and 1988 reveals that the proposer types were represented in about the same relative numbers. Both rounds were dominated by proposals submitted by individuals from the academic community followed by the consulting community (figure 11). A similar pattern emerges with a comparison of proposer's affiliation who received funding in 1987 and 1988 (figure 12). A notable difference is the decrease in the number of industry projects funded in the 1988 round.

CONCLUSIONS

The first two rounds of informal solicitations met or exceeded UGMS expectations. This procedure has proven to be an effective way to obtain and disseminate existing and new geologic data pertaining to Utah. UGMS is confident that much of this information would not get published soon, if ever, without the small amount of funding this program provides. The Mineral Lease Special Projects Program also provides for more effective management of the UGMS budget. Most all of the proposals received by UGMS in these first two rounds have been strong proposals, thereby making the job of the UGMS and the Board members a difficult one in selecting the top proposals for the funding.

Now that the next cycle of Informal Solicitation for Proposals is in progress, the UGMS can look back at the 1987 and 1988 cycles and apply much of what was observed to the 1989 cycle. UGMS expects the funds available for the 1989 round will be roughly the same as the past two rounds, about $100,000. The UGMS also expects to fund about the same number of proposals (10 to 15) depending on the size of the individual proposals submitted. The 1989 round will consider all topics in geology equally (topics in economic geology, applied geology, etc.) and hopefully will fund proposals from each of the related programs of the UGMS. To add your name for future mailings of the Informal Solicitation for Proposals for Geologic Projects, contact the Utah Geological and Mineral Survey.

PROPOSALS
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

Utah Conference on the Potential Indoor Radon Hazard

Wednesday, June 21, 1989
State Office Building Auditorium
8 a.m. to 5 p.m.

CANCELLED

Sponsored by the Utah Geological and Mineral Survey, the Utah Bureau of Radiation Control, and the University of Utah Research Institute.

Objective

This conference will provide a forum for public education by presenting a non-technical overview of current radon research. Topics will emphasize factors affecting Utah and the Rocky Mountain region. Major topics to be considered will include a definition of the basis for current concern, and will trace the course of public and professional involvement from detection of the potential hazard through prevention or mitigation.

Scope

A 1-day symposium will be held in Salt Lake City in mid-June, 1989. The audience will be drawn primarily from the non-technical public of the Wasatch Front region who desire to obtain more information on this recently publicized potential health hazard. Admission will be free, but a modest charge will be made for a volume of symposium talks.

1989 USGS McKelvey Forum

Nearly 800 scientist and explorationists attended the Fifth Annual V.E. McKelvey Forum on Mineral Resources held in Reno, Nevada, January 24-26, 1989. The forum consisted of 26 oral and 66 poster presentations of current research activities by USGS scientists and co-workers. The presentations covered a broad range of topics in economic geology with a strong emphasis on gold deposits of the Great Basin. Abstracts of these presentations are available in U.S. Geological Survey Circular 1035. The UGMS, represented by John Hand and Mike Shubat, contributed to two of the poster sessions, which presented results of the Delta CUSMAP project and the Tooele Preassessment project.

GREAT SALT LAKE LEVEL

Date (1986)	Boat Harbor South Arm (in feet)	Saline North Arm (in feet)
Nov 01	4206.60	4205.65
Nov 15	4206.50	4205.60
Dec 01	4206.50	4205.60
Dec 15	4206.45	4205.60
Jan 01	4206.45	4205.65
Jan 15	4206.45	4205.70
Feb 01	4206.50	4205.70
Feb 15	4206.50	4205.75

Source: USGS provisional records.

UTAH DEPARTMENT OF NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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